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PICKERING NGS 1990 OUTAGE
VACUUM BUILDING
INSPECTION OF CONCRETE

Report No. 90-163-K

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ABSTRACT

The structural concrete in the interior and a portion of the exterior concrete of the Vacuum Building was inspected during the Pickering NGS 1990 Outage. The inspection consisted of visual observations, nondestructive testing, concrete coring and half-cell potential measurements. The concrete throughout the structure was found to be in good condition. One area of honeycombed concrete at the base of a column and exposed reinforcing steel in a few of the columns in the Emergency Water Storage Tank were repaired at the time of the inspection.

job	file	date	report no.
42-120-453	842.5 PIC A/B	August 30, 1990	90-163-K

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To Dr. C.F. Lee
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PICKERING NGS 1990 OUTAGE
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INSPECTION OF CONCRETE

1.0 INTRODUCTION

An inspection of the structural concrete of the Vacuum Building was carried out during the station outage in May 1990. The inspection concentrated on the interior of the building, although the concrete in a few external locations was also examined.

The inspection followed the program prepared by the Central Production Services Division (CPSD) (PNGS CPS-N-20000-0004) and included visual observations, nondestructive testing and the drilling of concrete cores to obtain laboratory test specimens and to expose reinforcing steel for examination. Locations inspected during the 1980 Outage were reexamined to determine whether or not changes had occurred in the concrete over the past ten years.

This report summarizes the results of the inspection, including deficiencies noted and the actions taken to repair them. Also included, for comparison, are data obtained during the 1980 Outage and reported in Research Division Report 80-418-K.

2.0 INSPECTION RESULTS

The layout of the Vacuum Building is given in Figures A and B.

2.1 Interior

2.1.1 Main Volume

Underside of Floor Slab

The underside of the floor slab, at Elevation 254', was inspected from the basement while the Vacuum Building was in operation, at atmospheric pressure, and immediately after the douse test. The inspection consisted of visual observations, ultrasonic pulse velocity measurements and strain gauge monitoring. In two areas, cracks were mapped in detail. After the 1980 inspection, an extensive program was undertaken to repair cracks by epoxy injection. During this inspection, selected repaired and unrepaired cracks were evaluated ultrasonically. The results of the nondestructive testing are given in Table 1.

A douse test of the Vacuum Building was carried out by Pickering Operations as part of the outage activities. The test was conducted near the end of the outage, after the inspection and repairs of the interior of the building had been completed. During the douse test, the main floor slab was inspected for leakage from the basement of the Vacuum Building.

The visual inspection of the floor slab, while the Vacuum Building was in service, found the repairs to cracks to be intact with no evidence of leakage. Minor extensions of existing cracks were noted in a few locations.

When the Vacuum Building was brought to atmospheric pressure, leakage was observed at four locations along construction joints. No leakage was observed at these locations after the douse test. The construction joints, at Elevation 254', were re-caulked prior to the douse test and this may account for the absence of leakage observed at these locations.

The ultrasonic pulse velocity measurements in Table 1 include the results obtained during an inspection conducted in 1985 and reported in Research Division Report S87-9-K. The readings did not appear to vary significantly, although the values obtained while the structure was under vacuum were marginally higher than those taken after the douse test.

In 1980, electronic strain gauges and mechanical Pfender gauges were installed on the exterior of the Vacuum Building wall (north quadrant of the building) and on the underside of the main floor slab. During this inspection, the electronic strain gauges on the exterior of the building were not performing properly and were removed. The readings obtained from the Pfender and the remaining electronic strain gauges are plotted in Appendix A.

Prior to the douse test, additional electronic strain gauges were installed on the perimeter of the building and on the underside of the main floor slab (Figure 1). These gauges were monitored at half-second intervals during the douse test. The results are plotted in Appendix A.

The two locations selected for detailed crack mapping represented one area containing a large number of cracks (Figure 2) and the other area containing relatively few. A few additional hairline cracks were observed in these areas after the building was brought to atmospheric pressure and after the douse test. In one area, a crack was noted along a repair (Figure 3).

Accessible areas of the Vacuum Building floor slab were monitored for leakage immediately after the douse test and up to 24 hours afterwards. Leakage was noted primarily along the interface of the floor and columns (Figure 4), along unrepaired cracks and along extensions to repaired cracks (Figure 5). The most significant leakage was noted along the west side of Col G11 and along the east side of Col G9. The total leakage after the douse test was estimated to be 10.5 L/hr after two hours, 5.0 L/hr after four hours, and less than 2.0 L/hr after 24 hours. The leakage at two and four hours was determined while the water in the main volume was at its maximum level. No leakage was observed at repaired cracks. See Research Division Report 90-209-K for a detailed description of the douse test.

Floor Slab

The floor slab, at Elevation 254', was covered with a hard deposit which was removed at selected locations to inspect the concrete. The areas that were inspected in 1980 were visually reexamined and tested nondestructively. Concrete cores were also drilled from the floor slab, in the vicinity of Col E6, to obtain specimens for laboratory testing and to expose reinforcing steel for half-cell potential measurements. The results of the nondestructive testing are given in Table 2. A concrete core log with the results of the laboratory testing is given in Appendix B and the results of the half-cell potential measurements are given in Appendix C.

The impact hammer readings were similar to those reported in 1980, and the ultrasonic pulse velocity readings, through the slab, were somewhat lower.

At Col G9, the depth of crack penetration was estimated using ultrasonic pulse velocity measurements. The cracks were generally filled with material that prevented effective estimation of crack depths. The exceptions were sections of two cracks, at construction joints, that were estimated to extend at least 150 mm and 120 mm into the concrete.

The concrete coring confirmed the good quality of the concrete. Laboratory testing of the core specimens gave average compressive strength, ultrasonic pulse velocity, absorption and density of 35.6 MPa, 4690 m/s, 5.0%, and 2377 kg/m^3, respectively.

The reinforcing steel exposed for half-cell potential measurements was in good condition and showed no signs of corrosion. The half-cell potential measurements, performed in the vicinity of Cols E6 and J5, concluded that there was a greater than 90% probability that no corrosion of the reinforcing steel was taking place in these areas at the time of the test. Similar results were obtained in 1980.

Perimeter Wall

The perimeter wall, where accessible, was visually inspected and evaluated nondestructively. Ultrasonic pulse velocity readings were taken on the surface and through the wall at Elevation 254'. Impact hammer readings were taken at various locations, including areas accessible from the ladder behind Col A7. The test results are given in Table 3.

At Elevations 348' and 371.5', horizontal cracks with efflorescence were noted in the wall behind Col A7. These were measured at Elevation 371.5' to be 0.10 to 0.13 mm wide (Figure 6). The results of the nondestructive testing indicated a concrete of good quality, and were either higher than or similar to the readings obtained in 1980. The ultrasonic pulse velocity measurements through the wall were taken using the Soniscope. In each case, the readings and wave forms, which were saved on computer file for future reference, indicated a good quality concrete.

Columns

The columns were inspected from the basement, from the floor slab at Elevation 254' and from accessible locations at Elevations 348' and 371.5'. At each elevation, the columns were visually examined and the condition of selected columns were evaluated nondestructively. The test results are given in Table 4, including the results obtained in 1980.

At Elevation 254', many of the columns contained vertical cracks which were up to 0.30 mm wide. Efflorescence was generally associated with these cracks (Figures 7 and 8) which were more prominent in the columns around the perimeter of the building. Ultrasonic pulse velocity readings taken through a few of these columns represented good quality concrete, indicating that these cracks only affected the surface of the concrete. A smaller number of vertical cracks, up to 0.25 mm wide, were also noted in the columns at higher elevations.

In 1980, similar cracks, having a maximum width of 0.13 mm and exhibiting efflorescence, were observed in the columns. Over the past 10 years, the cracks appear to have increased in width. The nondestructive test results indicated that the concrete was of good quality.

Beams

In the main volume, the beams at Elevation 277.5' were visually inspected from the floor, and eight were accessed and evaluated nondestructively. The nondestructive evaluation consisted of ultrasonic pulse velocity readings taken through the beams and impact hammer readings taken on the surfaces. At Elevations 348' and 371.5', accessible beams were visually inspected and a few were evaluated nondestructively. The results of the testing, including the results from the three beams investigated in 1980, are given in Table 5.

Some of the beams at Elevation 277.5', particularly around the perimeter of the building, exhibited numerous hairline cracks with efflorescence. A number of these were evaluated nondestructively, and the results indicated that the concrete was of good quality. The cracks were probably a surface feature and did not extend deeper.

At Elevation 348' and 371.5', cracks were observed extending longitudinally along the centre of some beams. At one location, these cracks were measured to be 0.60 mm wide. Numerous hairline cracks with efflorescence were also observed at these elevations (Figure 9).

In 1980, minor cracking was reported in one of the beams investigated at Elevation 277'. It therefore appears that cracks in the concrete have become more numerous, with increased efflorescence over the last 10 years.

The nondestructive test results were in the range associated with a good quality concrete. The ultrasonic pulse velocity readings through the beams were generally lower than those recorded in 1980, while the impact hammer readings were higher.

2.1.2 EMERGENCY WATER STORAGE TANK

Underside of Floor Slab

The underside of the Emergency Water Storage Tank (EWST) floor slab was visually inspected at accessible locations from Elevations 371.5'. In general, the concrete appeared to be in good condition. Efflorescence, noted along a few cracks, indicated that leakage through the concrete had probably occurred. Efflorescence was noted at the following locations:

- crack extending to the southeast of Col E3

- along the beams extending from Col G7 (Figure 10)

- crack at embedded part between Cols G7 and G8

- along the beams extending from Col J7

- crack extending to the northwest of Col H7 (Figure 11)

Floor Slab

The floor slab of the EWST was covered with a hard deposit that had to be removed before the concrete could be visually inspected or evaluated nondestructively. The deposit was removed at three locations, and concrete cores were drilled from two locations to provide laboratory test specimens and to expose the reinforcing steel for half-cell potential measurements to determine the potential for corrosion. The results of the nondestructive testing are given in Table 6 and a concrete core log, with the laboratory test results, is given in Appendix B. The results of the half-cell potential measurements are given in Appendix C.

The areas of the floor slab evaluated during this inspection were also evaluated in 1980. As in the previous inspection, attempts were made to estimate the depth of the cracks ultrasonically. The cracks were found to be filled with material which prevented the estimating of crack depth. These test results were inconclusive and have not been included in Table 6. The cracks inspected ranged in width from 0.05 to 0.20 mm. Similar crack widths were reported in 1980.

The testing of concrete cores confirmed the good quality of the concrete. The compressive strength, ultrasonic pulse velocity, absorption and density of the concrete averaged 33.7 MPa, 4500 m/s, 4.8% and 2355 kg/m^3, respectively.

Reinforcing steel was exposed by drilling at two locations. Additional reinforcing steel was exposed as part of other inspection activities at approximately four locations. All of the exposed steel was in good condition and showed no signs of corrosion. The half-cell potential measurements carried out in the vicinity of Col J5 and Col E9 indicated that there was a 90% probability that corrosion of the reinforcing steel was not occurring in these areas at the time of the inspection. Similar results were obtained in 1980.

Underside of Roof Slab

The underside of the Vacuum Building roof slab was visually inspected from the floor (Elevation 395') of the EWST and in a few locations from man lifts. The presence of efflorescence along cracks indicated that water had leaked through the concrete in the following areas:

- cracks extending to the northwest, northeast and southeast of Col H3 (Figure 12)

- cracks extending to the northwest, northeast and southwest of Col G7

- cracks extending to the northwest and southwest of Col F11 (Figure 13)

- cracks extending to the southwest of Col L7

Perimeter Wall

The perimeter wall was visually inspected and evaluated nondestructively at the two locations evaluated in 1980. The test results are given in Table 7.

No visual deterioration of the concrete was noted, although some fine map cracking was present. The results of the nondestructive testing indicated that the concrete was of good quality, and were generally higher than the results obtained in 1980.

Columns

All of the columns in the EWST were visually examined and six were evaluated nondestructively. The test results are reported in Table 8.

In 1980, the columns in the EWST were reported to be in good condition with some hairline cracks and no rust stains. During this inspection, the columns were observed to contain cracks with widths of less than 0.05 mm. In addition, staining as a result of steel corrosion was observed on 21 of the 37 columns in the tank. In most cases, the staining was localized in nature and only affected a small area. The exception was four columns (G6, G9, L7, E5) where the corrosion had reached the extent that repairs were carried out. The cause of the corrosion appeared to be insufficient concrete cover over the reinforcing steel (Figures 14 and 15). In each of the four columns repaired, the spiral reinforcing steel had less than 15 mm of concrete cover. The maximum reduction of steel cross-sectional area as a result of corrosion, was visually estimated to be about 20%. Other

than the corroded areas, the exposed steel appeared to be in good condition. Half-cell potential measurements of selected columns adjacent to Cols E5 and G9, reported in Appendix C, concluded that there was over a 90% probability that no corrosion was occurring at the time of the inspection.

At the base of Col E3, which forms part of the perimeter wall, an area of honeycombed concrete was noted (Figure 16). The poor quality concrete in this area was removed and the area repaired with dry-pack mortar blended with a latex cement slurry. All of the reinforcing steel exposed was in good condition and did not exhibit corrosion.

The results of the nondestructive testing were in the range associated with good quality concrete and were generally higher than those reported in 1980.

Beams

Six beams in the EWST were inspected in detail. Of these beams, three had been inspected during the outage in 1980. The results of the nondestructive tests are given in Table 9.

Visually, only a few hairline cracks with efflorescence were observed (Figure 17). The test results indicated that the concrete in the areas investigated was of good quality, and were similar to those obtained in 1980.

2.2 Exterior

The inspection of the exterior of the Vacuum Building concentrated on the roof.

At two locations on the roof, cracks in the concrete were nondestructively evaluated (Figure 18). The concrete in these areas had been parged, and this combined with material in the crack made it difficult to determine the depth of crack penetration. The test results are given in Table 10.

A number of cracks had been previously repaired around the edge of the roof slab, above the roof seal (Figure 19). Additional cracks and extensions to repaired cracks were noted. Ultrasonic pulse velocity measurements were taken in four locations that appear to have been tested previously. The results are given in Table 10.

2.3 Upper Chambers

The interior of the east and west upper chambers was visually inspected. The concrete appeared to be in good condition with only minor hairline cracks.

Although the exterior of the upper chambers had been parged, a visual inspection revealed a few minor popouts. These were generally caused by corrosion of steel near the surface of the concrete (Figure 20).

3.0 DEFICIENCIES AND REMEDIAL ACTION

Only two deficiencies were identified during this inspection, and these were associated with the columns in the EWST.

(a) In four of the columns (G6, G9, L7, E5), the spiral reinforcing steel had corroded as a result of insufficient concrete cover (Figures 14 and 15). These areas were repaired by removing the surrounding concrete and replacing it with a sand filled epoxy mortar.

(b) The other defect identified was an area of honeycombed concrete at the base of Col E3 in the wall of the EWST. This defect was probably construction related. The unsound concrete was removed and replaced with dry-pack mortar blended with a latex cement slurry. All reinforcing steel exposed as part of this repair was in good condition, with no evidence of corrosion (Figure 16).

4.0 SUMMARY AND CONCLUSIONS

1. The concrete inspected in the Vacuum Building was in good condition.

2. The only leakage observed after the douse test was at unrepaired locations and was estimated to be a maximum of 10.5 L/hr two hours after the test, with a full head of water on the floor.

3. Horizontal cracks with efflorescence were noted in the perimeter wall of the main volume at Elevation 371.5'. These cracks were 0.10 to 0.13 mm wide. In 1980, some minor surface cracks were reported at Elevation 300'.

4. At Elevation 254', vertical cracks in the columns of the main volume appear to have increased in width and number since 1980. The structural significance of this change should be reviewed.

5. Cracking of the beams in the main chamber appears to have increased since 1980, although they remain <0.05 mm in width. The structural significance of this change should be reviewed.

6. In the EWST, corrosion of spiral reinforcing steel was observed in a number of the columns. Four columns required repair to protect the reinforcing steel.

7. One area of honeycombed concrete in a column of the perimeter wall of the EWST was repaired.

5.0 INSPECTION TEAM

The inspection of the concrete in the Vacuum Building during the Pickering NGS 1990 outage was carried out by H. Caratin, E.J. McColm, J. Vitanyi, C.J. Hernes, M.F. Everitt, and J. Aloisio with assistance from J.J. Deans and P. Huynh of the Concrete Technology Section, Civil Research Department. The half-cell potential readings were carried out by A. Headon and B. Guest of the Metallurgical Research Department.

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TABLE 1
PICKERING NGS 1990 OUTAGE
UNDERSIDE OF VACUUM BUILDING FLOOR SLAB
NONDESTRUCTIVE TEST RESULTS

LOCATION	READING ID	DURING OPERATION	AT ATMOSPHERIC PRESSURE	AFTER DOUSE TEST	READINGS TAKEN IN 1985*
Ultrasonic Pulse Velocity Readings (m/s)					
- Repaired crack east of Col C7 - no extension of crack or cracking of epoxy	A B C D AVG	4900 4600 4600 4500 4650	4600 4600 4600 4800 4650	4300 4400 4200 4100 4250	4500 4500 4300 4200 4380
Ultrasonic Pulse Velocity Readings (m/s)					
- Repaired crack northwest of Col E7 - no extension of crack or cracking of epoxy	A B C D E AVG	4800 4500 4700 4500 4500 4600	4400 4500 4400 4400 4500 4440	4400 4500 4200 4700 4400 4440	4400 4400 4400 4500 4600 4460
Ultrasonic Pulse Velocity Readings (m/s)					
- Repaired crack west of Col E7 - no extension of crack or cracking of epoxy	A B C D E AVG	4500 4700 4800 4600 - 4650	4200 4700 4300 4100 4400 4340	4200 4600 4400 4200 4300 4340	4400 4400 4500 4500 4300 4420
Estimated Depth of Crack (mm)					
- Unrepaired crack east of Col E6 - crack width 0.13 to 0.15 mm	A B C AVG	160 190 200 180	140 170 170 160	160 140 170 160	- - - -
	Ultrasonic Pulse Velocity Readings (m/s)				
(Sound concrete**) (Sound concrete)	AB E	4200 4200	3600 4100	3800 4000	- -

* During Operation - See Research Division Report S87-9-K

** Low Ultrasonic Pulse Velocity Readings (<3700 m/s) obtained from the sound concrete are probably the result of hairline cracks in the floor slab.

TABLE 1 (CONT'D)
PICKERING NGS 1990 OUTAGE
UNDERSIDE OF VACUUM BUILDING FLOOR SLAB
NONDESTRUCTIVE TEST DATA

LOCATION	READING ID	DURING OPERATION	AT ATMOSPHERIC PRESSURE	AFTER DOUSE TEST	READINGS TAKEN IN 1985*
Ultrasonic Pulse Velocity Readings (m/s)					
- Repaired crack east of Col E7	A	4600	4400	4300	4400
- no extension of crack or cracking of epoxy	B	4400	4200	4400	4500
	C	3300	3200	3300	3400
	D	4400	4300	4400	4500
	AVG	4180	4030	4100	4200
Estimated Depth of Crack (mm)					
- Unrepaired crack west of Col E8	A	210	210	190	-
- crack width 0.05 to 0.15 mm	B	210	220	200	-
	C	240	230	210	-
	D	170	230	170	-
	AVG	180	220	190	-
	Ultrasonic Pulse Velocity Readings (m/s)				
(Sound concrete)	BC	4100	4100	4200	-
(Sound concrete)	AB	4300	4000	3800	-
Ultrasonic Pulse Velocity Readings (m/s)					
- Repaired crack north of Col E8	A	4100	4400	4300	4500
- crack has extended 180 mm since epoxy repair was carried out (width < 0.05 mm)	B	4000	4100	4100	4400
	C	4000	4100	4200	4300
	AVG	4030	4200	4200	4400
Ultrasonic Pulse Velocity Readings (m/s)					
- Repaired crack southwest of Col E6	A	4700	4400	4500	4400
- no extension of crack or cracking of epoxy	B	4800	4400	4600	4500
	C	4200	4200	4400	4200
	D	3000	3100	3000	-
	AVG	4180	4030	4130	4370

* During Operation - See Research Division Report S87-9-K.

TABLE 1 (CONT'D)
PICKERING NGS 1990 OUTAGE
UNDERSIDE OF VACUUM BUILDING FLOOR SLAB
NONDESTRUCTIVE TEST DATA

LOCATION	READING ID	DURING OPERATION	AT ATMOSPHERIC PRESSURE	AFTER DOUSE TEST	READINGS TAKEN IN 1985*
		Ultrasonic Pulse Velocity Readings (m/s)			
- Repaired crack south of Col E5 - no extension of crack or cracking of epoxy	A B C AVG	4400 4100 4400 4300	4600 4100 4400 4370	4800 4200 4600 4530	4600 4500 4500 4530
Between Cols C5 and D4	- pattern cracking noted (width <0.05 mm) - no readings taken				
		Ultrasonic Pulse Velocity Readings (m/s)			
- Repaired crack south of Col G3 - no extension of crack or cracking of epoxy	A B C D E AVG	4600 4400 4600 4400 4400 4480	4400 4200 4600 4400 4000 4320	4300 4400 4300 4300 4100 4280	4200 4200 4500 4200 4100 4240
		Estimated Depth of Crack (mm)			
- Unrepaired crack south of Col G3 - crack width 0.05 to 0.10 mm	A B C D AVG	220 190 200 220 210	170 210 160 190 180	130 140 120 100 120	- - - - -
		Ultrasonic Pulse Velocity Readings (m/s)			
(Sound concrete)	CD	4400	4200	3700	-
		Ultrasonic Pulse Velocity Readings (m/s)			
- Repaired crack north of Col G9 - no extension of crack or cracking of epoxy	A B C AVG	4000 4900 4600 4500	4200 4500 4800 4500	3900 4700 4200 4270	4100 4500 4300 4300

* During Operation - See Research Division Report S87-9-K.

TABLE 1 (CONT'D)
PICKERING NGS 1990 OUTAGE
UNDERSIDE OF VACUUM BUILDING FLOOR SLAB
NONDESTRUCTIVE TEST DATA

LOCATION	READING ID	DURING OPERATION	AT ATMOSPHERIC PRESSURE	AFTER DOUSE TEST	READINGS TAKEN IN 1985*
Ultrasonic Pulse Velocity Readings (m/s)					
- Repaired crack south of Col F11	A	3400	3900	3900	4000
- no extension of crack	B	2800	3300	3300	3300
or cracking of epoxy	C	4400	4400	4200	4100
	D	4300	4200	3800	3600
	AVG	3730	3950	3800	3750
Ultrasonic Pulse Velocity Readings (m/s)					
- Repaired crack north of Col J5	A	4300	4300	4600	-
- crack has extended	B	4500	4400	4800	-
330 mm since epoxy	C	4300	4300	4400	-
repair was carried out	D	4500	4400	4400	-
(width < 0.05 mm)	E	4200	4100	4100	-
	AVG	4360	4300	4460	-
Estimated Depth of Crack (mm)					
- Unrepaired crack between Cols H3 and J3	A	190	170	140	-
- small cracks were	B	170	170	170	-
noted throughout the	C	180	160	150	-
concrete including the	D	0	0	0	-
area used to represent	E	170	160	140	-
sound concrete	F	180	160	150	-
- crack width 0.05 mm	AVG	150	140	130	-
	Ultrasonic Pulse Velocity Readings (m/s)				
(Sound concrete**)	DE (west)	3700	3400	3200	-
(Sound concrete)	DE (east)	3700	4500	-	-
(Sound concrete**)	AB (west)	4000	3600	3700	-
(Sound concrete**)	AB (east)	3800	3500	3500	-

* During Operation - See Research Division Report S87-9-K

** Low Ultrasonic Pulse Velocity Readings (<3700 m/s) obtained from the sound concrete are probably the result of hairline cracks in the floor slab.

TABLE 1 (CONT'D)
PICKERING NGS 1990 OUTAGE
UNDERSIDE OF VACUUM BUILDING FLOOR SLAB
NONDESTRUCTIVE TEST DATA

LOCATION	READING ID	DURING OPERATION	AT ATMOSPHERIC PRESSURE	AFTER DOUSE TEST	READINGS TAKEN IN 1985*
Ultrasonic Pulse Velocity Readings (m/s)					
- Repaired crack east of Col H6	A	4000	4000	4000	-
- crack has extended 150 mm since epoxy repair was carrid out	B	4000	3800	3800	-
	C	4000	4000	4000	-
	AVG	4000	3930	3930	-
Estimated Depth of Crack (mm)					
- Unrepaired crack east of Col H6	A	120	120	120	-
- crack width 0.05 mm	B	110	140	110	-
	C	150	170	160	-
	AVG	130	140	130	-
	Ultrasonic Pulse Velocity Readings (m/s)				
(Sound concrete**)	AB (south)	3500	3400	3300	-
(Sound concrete**)	AB (north)	3600	3700	3800	-
Estimated Depth of Crack (mm)					
- Unrepaired crack east of Col G6	A	180	180	130	-
- Too many cracks were present to get stable reading of sound concrete. Assumed a velocity of 4200 m/sec	B	160	170	160	-
	C	180	220	180	-
- crack width <0.05 mm	AVG	170	190	160	-

* During Operation - See Research Division Report S87-9-K

** Low Ultrasonic Pulse Velocity Readings (<3700 m/s) obtained from the sound concrete are probably the result of hairline cracks in the floor slab.

TABLE 2
PICKERING NGS 1990 OUTAGE
VACUUM BUILDING - FLOOR SLAB OF MAIN VOLUME (ELEVATION 254')
NONDESTRUCTIVE TEST DATA

LOCATION	ULTRASONIC PULSE VELOCITY READINGS (m/s)**	IMPACT HAMMER READINGS*	
		AVERAGE REBOUND NUMBER	RELATIVE STRENGTH (MPa)
Area northwest of Col H7			
- readings taken in 1990	-	45.0	46
- readings taken in 1980	-	47.1	49
Area northwest of Col J5			
- readings taken in 1990	-	47.6	50
- readings taken in 1980	-	51.2	55
Area southwest of Col G9			
- readings taken in 1990	-	52.3	58
- readings taken in 1980	-	51.6	57
Area south of Col G9			
- readings taken in 1990	-	54.1	59
- readings taken in 1980	-	54.5	60
Area east of Col G9			
- readings taken in 1990	-	54.5	59
- readings taken in 1980	-	53.4	59
Area northwest of Col G8			
- readings taken in 1990	-	46.6	48
- readings taken in 1980	-	49.6	53
Area northwest of Col E8			
- readings taken in 1990	-	46.4	48
Area southeast of Col E8			
- readings taken in 1990	-	42.9	43
Readings through floor slab northwest of Hatch 2 and east of Col F3 - readings taken in 1990	Reading: 1 A 4200 B 4200; 2 A 4200 B 4100; 3 A 4200 B 4200; 4 A 4200 B 4200; 5 A 4200 B 4200; 6 A 4200 B 4300	-	-
Reading through floor slab near Hatch 2 obtained in 1980	4500	-	-

* The impact hammer does not give an absolute value for the strength of the concrete. It actually gives a relative strength value, based on the surface concrete that can be used for comparison purposes.

** Ultrasonic Pulse Velocity Readings were taken on a grid identified 1 to 6 and A and B.

TABLE 3
PICKERING NGS 1990 OUTAGE
VACUUM BUILDING - PERIMETER WALL IN MAIN VOLUME
NONDESTRUCTIVE TEST DATA

LOCATION	ULTRASONIC PULSE VELOCITY READINGS (m/s)**				IMPACT HAMMER READINGS*	
					AVERAGE REBOUND NUMBER	RELATIVE STRENGTH (MPa)
Elevation 254'	Reading					
Surface readings on wall behind Col H2		A	B	C	47.7	46
- readings taken in 1990	1	4700	5000	4700		
	2	4800	5000	4800		
	3	4800	4800	4800		
	4	4700	5000	4700		
	5	-	4800	5100		
- readings taken in 1980		A	B	C	48.3	47
	1	4800	4800	4800		
	2	4900	4800	-		
	3	5100	4700	4800		
	4	4800	4700	-		
	5	4800	4800	4800		
Surface readings on wall behind Col G13		A	B	C	47.2	46
- readings taken in 1990	1	4700	4700	4700		
	2	4600	4500	4700		
	3	4600	4400	4700		
	4	4700	4800	4900		
	5	5100	4800	4800		
- readings taken in 1980		A	B	C	50.4	51
	1	5000	4800	5000		
	2	5100	4800	-		
	3	5000	4700	4800		
	4	4800	4600	-		
	5	4800	5000	4800		

* The impact hammer does not give an absolute value for the strength of the concrete. It actually gives a relative strength value, based on the surface concrete, that can be used for comparison purposes.

** Ultrasonic Pulse Velocity Readings were taken on a grid identified 1 to 5 and A to C.

TABLE 3 (CONT'D)
PICKERING NGS 1990 OUTAGE
VACUUM BUILDING - PERIMETER WALL IN MAIN VOLUME
NONDESTRUCTIVE TEST DATA

LOCATION	ULTRASONIC PULSE VELOCITY READINGS (m/s)**				IMPACT HAMMER READINGS*	
					AVERAGE REBOUND NUMBER	RELATIVE STRENGTH (MPa)
Readings through wall behind Col G1	Reading	A	B	C	-	-
- readings taken in 1990	1	4500	4500	4500		
	2	4500	4500	4500		
	3	4600	4600	4500		
- readings taken in 1980		4500 4600			-	-
Readings through wall behind Col G13		A	B	C		
- readings taken in 1990	1	4600	4600	4600		
	2	4500	4600	4500		
	3	4600	4400	4400		
- reading taken in 1980		4500			-	-
Wall behind Col A7						
- readings taken in 1990		-			48.5	48
- readings taken in 1980					47.7	46
Elevation 277.5'						
Wall behind Col A7						
- readings taken in 1990		-			50.9	52
- readings taken in 1980					47.2	46
Elevation 301'						
Wall behind Col A7						
- readings taken in 1990		-			52.5	54
- readings taken in 1980					44.9	42
Elevation 324.5'						
Wall behind Col A7						
- readings taken in 1990		-			46.3	44
- readings taken in 1980					39.0	33
Elevation 348'						
Wall behind Col A7						
- readings taken in 1990		-			49.6	50
- readings taken in 1980					40.0	34
Elevation 371.5'						
Wall behind Col A7						
- readings taken in 1990		-			49.1	48
- readings taken in 1980					45.0	42

* The impact hammer does not give an absolute value for the strength of the concrete. It actually gives a relative strength value, based on the surface concrete, that can be used for comparison purposes.

** Ultrasonic Pulse Velocity Readings were taken on a grid identified 1 to 3 and A to C.

TABLE 4
PICKERING NGS 1990 OUTAGE
VACUUM BUILDING - COLUMNS IN BASEMENT AND MAIN VOLUME
NONDESTRUCTIVE TEST DATA

LOCATION	ULTRASONIC PULSE VELOCITY READINGS (m/s)**			IMPACT HAMMER READINGS*	
				AVERAGE REBOUND NUMBER	RELATIVE STRENGTH (MPa)
Elevation 242'	Reading				
Col E6		N-S	E-W		
- readings taken in 1990	A	4700	-	South 49.2	49
	B	4700	-	North 49.9	50
	C	4600	-		
	D	4700	-		
Col E8		N-S	E-W		
- readings taken in 1990	A	4800	-	South 51.4	52
	B	4800	-	North 52.8	54
	C	4800	-		
	D	4800	-		
Col F3					
- readings taken in 1990		-		East 46.9	45
				South 47.7	46
Col F7		N-S	E-W		
- readings taken in 1990	A	4800	-	South 50.5	51
	B	4800	-	North 51.3	52
	C	4800	-		
	D	4800	-		
Col F9		N-S	E-W		
- readings taken in 1990	A	-	4800	East 51.9	53
	B	-	4800	West 51.3	52
	C	-	4700		
	D	-	4800		
Col G1					
- readings taken in 1990		-		South 49.2	49
				North 52.5	54
Col H2					
- readings taken in 1990		-		South 46.5	45
				North 45.5	43

* The impact hammer does not give an absolute value for the strength of the concrete. It actually gives a relative strength value, based on the surface concrete, that can be used for comparison purposes.

** Ultrasonic Pulse Velocity Readings, identified from A to D, were taken north-south (N-S) or east-west (E-W) through the columns.

TABLE 4 (CONT'D)
PICKERING NGS 1990 OUTAGE
VACUUM BUILDING - COLUMNS IN BASEMENT AND MAIN VOLUME
NONDESTRUCTIVE TEST DATA

LOCATION	ULTRASONIC PULSE VELOCITY READINGS (m/s)**			IMPACT HAMMER READINGS*	
				AVERAGE REBOUND NUMBER	RELATIVE STRENGTH (MPa)
Col H3	Reading	N-S	E-W		
- readings taken in 1990	A	4900	-	-	-
	B	4800	-		
	C	4900	-		
	D	4900	-		
Col H5		N-S	E-W		
- readings taken in 1990	A	4400	4300	East 51.6	53
	B	4500	4500	West 51.5	53
	C	4500	4500		
	D	4500	4500		
Col H6					
- readings taken in 1990		-		South 49.3	50
				North 51.1	52
Elevation 254'					
Col B8		N-S	E-W		
- readings taken in 1990	A	4800	4800	East 53.5	55
- numerous vertical cracks up to 0.25 mm wide	B	4900	4800	West 54.6	58
	C	4900	4800		
	D	4900	4800		
Col D4		N-S	E-W		
- readings taken in 1990	A	4800	4800	East 53.5	56
- vertical cracks up to 0.13 mm wide	B	4800	4800	West 52.9	55
	C	4800	4800		
	D	4900	4900		
Col E8		N-S	E-W		
- readings taken in 1990	A	4800	4800	East 55.2	59
- vertical cracks generally 0.020 mm wide, although at least one was 0.30 mm wide	B	4900	4800	West 54.1	57
	C	4900	4800		
	D	4900	4800		

* The impact hammer does not give an absolute value for the strength of the concrete. It actually gives a relative strength value, based on the surface concrete, that can be used for comparison purposes.

** Ultrasonic Pulse Velocity Readings, identified from A to D, were taken north-south (N-S) or east-west (E-W) through the columns.

TABLE 4 (CONT'D)
PICKERING NGS 1990 OUTAGE
VACUUM BUILDING - COLUMNS IN BASEMENT AND MAIN VOLUME
NONDESTRUCTIVE TEST DATA

LOCATION	ULTRASONIC PULSE VELOCITY READINGS (m/s)**			IMPACT HAMMER READINGS*	
				AVERAGE REBOUND NUMBER	RELATIVE STRENGTH (MPa)
	Reading	N-S	E-W		
Col F7				East 52.0	54
- readings taken in 1990	A	4800	4700	West 53.6	56
	B	4800	4700		
	C	4800	4800		
	D	4900	4800		
- readings taken in 1980		4800	4700	-	-
Col G1					
- readings taken in 1990		-		East 52.9	55
				West 47.7	46
- readings taken in 1980				45.8	44
Col F3					
- readings taken in 1990		-		East 51.9	53
				West 50.1	50
- readings taken in 1980				49.6	50
Col H2					
- readings taken in 1990		-		East 52.6	54
				West 55.6	59
- readings taken in 1980				49.6	50
Col M8		N-S	E-W		
- readings taken in 1990	A	4800	4700	South 55.5	59
- vertical cracks generally less	B	4900	4700	North 55.6	59
than 0.13 mm wide, although at	C	4800	4700		
least one was 0.30 mm wide	D	4900	4800		
Elevation 348'					
Col A7					
- readings taken in 1990		-		56.6	59

* The impact hammer does not give an absolute value for the strength of the concrete. It actually gives a relative strength value, based on the surface concrete, that can be used for comparison purposes.

** Ultrasonic Pulse Velocity Readings, identified from A to D, were taken north-south (N-S) or east-west (E-W) through the columns.

TABLE 4 (CONT'D)
PICKERING NGS 1990 OUTAGE
VACUUM BUILDING - COLUMNS IN BASEMENT AND MAIN VOLUME
NONDESTRUCTIVE TEST DATA

LOCATION	ULTRASONIC PULSE VELOCITY READINGS (m/s)	IMPACT HAMMER READINGS*	
		AVERAGE REBOUND NUMBER	RELATIVE STRENGTH (MPa)
Col B6 - readings taken in 1990	-	53.9	57
Col B8 - readings taken in 1990	-	53.1	55
Elevation 371.5' Col A7 - readings taken in 1990 - vertical cracks up to 0.25 mm wide - no efflorescence present	-	49.3	49
Col E8 - readings taken in 1990 - one vertical crack with width less than 0.05 mm	-	51.6	52
- readings taken in 1980	-	51.5	53
Col E5 - readings taken in 1990 - no cracks noted	-	52.0	54
Col F7 - readings taken in 1990 - no cracks noted	-	51.5	53
Col C8 - readings taken in 1990 - no cracks noted	-	53.5	56
Col C6 - readings taken 1980	-	51.6	53

* The impact hammer does not give an absolute value for the strength of the concrete. It actually gives a relative strength value, based on the surface concrete, that can be used for comparison purposes.

TABLE 5
PICKERING NGS 1990 OUTAGE
VACUUM BUILDING - BEAMS IN MAIN VOLUME
NONDESTRUCTIVE TEST DATA

LOCATION	ULTRASONIC PULSE VELOCITY READINGS (m/s)**				IMPACT HAMMER READINGS*		
					AVERAGE REBOUND NUMBER		RELATIVE STRENGTH (MPa)
	Reading						
Elevation 277.5		A	B	C			
Beam between Cols J9 and L9	1	4800	4700	4700	East	52.1	54
- readings taken in 1990	2	4700	4700	4700	West	51.2	52
- some hairline cracks with	3	4800	4800	4700			
efflorescence	4	4800	4800	4700			
	5	4700	4700	4600			
	6	4700	4700	4700			
	7	4800	4700	4700			
		A	B	C			
- readings taken in 1980	1	4800	4700	4800		50.4	51
	2	4800	4800	4700			
	3	4800	4800	4700			
	4	4900	4800	4800			
	5	4700	4800	4700			
	6	4800	4800	4700			
	7	4800	4800	4800			
Beam between Cols J7 and L7		A	B	C			
- readings taken in 1990	1	4800	4800	4900	East	52.5	54
- no significant cracking noted	2	4800	4800	4800	West	53.6	56
	3	4700	4800	4800			
Beam between Cols H5 and J5		A	B	C			
- readings taken in 1990	1	4700	4600	4600	East	51.8	53
- no significant cracking noted	2	4600	4700	4700	West	52.5	54
	3	4700	4700	4700			
	4	4700	4700	4700			
	5	4700	4700	4800			
	6	4800	4800	4700			
	7	4800	4900	4800			
		A	B	C			
- readings taken in 1980	1	4700	4700	4700		49.4	49
	2	4700	4700	4700			
	3	4800	4700	4700			
	4	4800	4800	4700			
	5	4800	4800	4800			
	6	4800	4800	4800			
	7	4900	5000	4800			

* The impact hammer does not give an absolute value for the strength of the concrete. It actually gives a relative strength value, based on the surface concrete, that can be used for comparison purposes.

** Ultrasonic Pulse Velocity Readings were taken through the beam on a grid identified 1 to 7 and A to C.

TABLE 5 (CONT'D)
PICKERING NGS 1990 OUTAGE
VACUUM BUILDING - BEAMS IN MAIN VOLUME
NONDESTRUCTIVE TEST DATA

LOCATION	ULTRASONIC PULSE VELOCITY READINGS (m/s)**				IMPACT HAMMER READINGS*		
					AVERAGE REBOUND NUMBER		RELATIVE STRENGTH (MPa)
	Reading						
Beam between Cols J5 and K5		A	B	C			
- readings taken in 1990	1	4900	4800	4700	Southeast	55.0	59
- extensive hairline cracks	2	4900	4800	4700	Northwest	54.5	58
with efflorescence	3	4900	4800	4700			
Beam between Cols F9 and F11		A	B	C			
- readings taken in 1990	1	4800	4800	4700	South	54.6	58
- some hairline cracks with	2	4800	4800	4800	North	54.2	57
efflorescence	3	4800	4800	4900			
Beam between Cols E9 and D10		A	B	C			
- readings taken in 1990	1	4700	4800	4800	Southeast	54.9	59
- some hairline cracks with	2	4800	5000	4800	Northwest	54.9	59
efflorescence	3	4800	4900	4900			
Beam between Cols E6 and F6		A	B	C			
- readings taken in 1990	1	4800	4700	4700	East	52.5	54
- no significant cracking noted	2	4800	4800	4800	West	53.4	56
	3	4800	4800	4900			
	4	4800	4800	4800			
	5	4800	4800	4800			
	6	4800	4800	4800			
	7	4800	4900	4900			
		A	B	C			
- readings taken in 1980	1	4800	4800	4800		49.0	48
	2	4800	4800	4800			
	3	4900	4900	4900			
	4	4900	4900	4900			
	5	4800	4900	4800			
	6	4900	4900	4900			
	7	4900	4900	4900			
Beam between Cols E3 an E5		A	B	C			
- readings taken in 1990	1	4800	4900	4800	South	55.5	59
- some hairline cracks with	2	4800	4800	4700	North	52.9	55
efflorescence	3	4800	4700	4800			
Elevation 348' Beam extending east from Col B6 - readings taken in 1990	-				53.2		51

* The impact hammer does not give an absolute value for the strength of the concrete. It actually gives a relative strength value, based on the surface concrete, that can be used for comparison purposes.

** Ultrasonic Pulse Velocity Readings were taken through the beam on a grid identified 1 to 7 and A to C.

TABLE 5 (CONT'D)
PICKERING NGS 1990 OUTAGE
VACUUM BUILDING - BEAMS IN MAIN VOLUME
NONDESTRUCTIVE TEST DATA

LOCATION	ULTRASONIC PULSE VELOCITY READINGS (m/s)**	IMPACT HAMMER READINGS*	
		AVERAGE REBOUND NUMBER	RELATIVE STRENGTH (MPa)
Beam extending west from Col B6 - readings taken in 1990	-	47.2	41
Beam extending east from Col B8 - readings taken in 1990	-	50.1	46
Beam extending west from Col B8 - readings taken in 1990	-	55.4	54
Elevation 371.5' Beam extending east from Col E8 - readings taken in 1990	-	46.0	38
Beam extending south from Col E8 - readings taken in 1990	-	48.8	43
Beam extending west from Col E8 - readings taken in 1990	-	49.0	43
Beam extending north from Col E8 - readings taken in 1990	-	47.9	41
Beam extending south from Col G8 - readings taken in 1990	-	51.7	48
Beam extending west from Col G8 - readings taken in 1990	-	49.9	45
Beam extending north from Col G8 - readings taken in 1990	-	52.2	49

* The impact hammer does not give an absolute value for the strength of the concrete. It actually gives a relative strength value, based on the surface concrete, that can be used for comparison purposes.

** Ultrasonic Pulse Velocity Readings were taken through the beam on a grid identified 1 to 7 and A to C.

TABLE 6
PICKERING NGS 1990 OUTAGE
VACUUM BUILDING - FLOOR SLAB IN EWST
NONDESTRUCTIVE TEST DATA

LOCATION	ULTRASONIC PULSE VELOCITY READINGS (m/s)		IMPACT HAMMER READINGS*	
			AVERAGE REBOUND NUMBER	RELATIVE STRENGTH (MPa)
South of Col E5				
- readings taken in 1990	Sound concrete	5200	52.0	57
		5000	54.2	>59
- readings taken in 1980	Sound concrete	4700	50.5	54
		4600		
Northwest of Col G9				
- readings taken in 1990	Sound concrete	5100	52.0	57
		4900	52.6	58
- readings taken in 1980	Sound concrete	5100	50.5	54
East of Col G5				
- Readings taken in 1990	Sound concrete	5000	54.4	>59
		5000	53.0	59
- readings taken in 1980	Sound concrete	5100	53.3	59
		5100		
		5300		

* The impact hammer does not give an absolute value for the strength of the concrete. It actually gives a relative strength value, based on the surface concrete, that can be used for comparison purposes.

TABLE 7
PICKERING NGS 1990 OUTAGE
VACUUM BUILDING - PERIMETER WALL OF EWST
NONDESTRUCTIVE TEST DATA

LOCATION	ULTRASONIC PULSE VELOCITY READINGS (m/s)**				IMPACT HAMMER READINGS*	
					AVERAGE REBOUND NUMBER	RELATIVE STRENGTH (MPa)
	Reading					
Elevation 395		A	B	C		
Surface readings on wall	1	4900	4800	5000	50.4	51
behind Col G3	2	4900	5100	4900		
- readings taken in 1990	3	5100	4900	4800		
	4	4800	4800	4900		
	5	5000	5000	4800		
		A	B	C		
- readings taken in 1980	1	5100	4600	4900	49.5	50
	2	4800	4600	-		
	3	4700	4800	4800		
	4	4700	4600	-		
	5	4800	4500	4600		
Surface readings on wall		A	B	C		
behind Col G11	1	5300	5300	5000	51.8	53
- readings taken in 1990	2	4600	5100	4700		
	3	4800	4900	4800		
	4	5300	4800	4900		
	5	5100	4800	4800		
		A	B	C		
- readings taken in 1980	1	4800	5000	4900	48.6	48
	2	4900	4800	-		
	3	5000	4900	4800		
	4	4800	4700	-		
	5	4700	4500	4700		

* The impact hammer does not give an absolute value for the strength of the concrete. It actually gives a relative strength value, based on the surface concrete, that can be used for comparison purposes.

** Ultrasonic Pulse Velocity Readings were taken on a grid identified 1 to 5 and A to C.

TABLE 8
PICKERING NGS 1990 OUTAGE
VACUUM BUILDING - COLUMNS IN EWST
NONDESTRUCTIVE TEST DATA

LOCATION	ULTRASONIC PULSE VELOCITY READINGS (m/s)**			IMPACT HAMMER READINGS*		
				AVERAGE REBOUND NUMBER		RELATIVE STRENGTH (MPa)
	Reading					
Elevation 395'		N-S	E-W			
Col C7	A	4800	4800	North	51.8	53
- readings taken in 1990	B	4800	4800	South	50.9	52
- vertical hairline cracks less	C	4700	4700			
than 0.05 mm wide	D	4800	4800			
	E	4700	4700			
	F	4800	4800			
Col E9		N-S	E-W			
- readings taken in 1990	A	5000	5000	Northwest	54.8	58
	B	4900	5000	Southeast	53.6	56
	C	4900	4900			
	D	5000	4900			
	E	5000	5000			
Col F5		N-S	E-W			
- readings taken in 1990	A	5000	5000	Northwest	52.5	54
- vertical hairline cracks less	B	4900	5000	Southeast	53.3	56
than 0.05 mm wide	C	4900	5000			
	D	5000	5000			
	E	5000	5000			
	F	5000	5000			
		N-S	E-W			
- readings taken in 1980	A	5000	-		48.6	48
	B	4900	-			
	C	4900	-			
	D	4900	-			
	E	4900	-			
	F	4900	-			
Col G7		N-S	E-W			
- readings taken in 1990	A	5000	5000	East	51.8	53
- vertical hairline cracks less	B	4800	4900	West	50.6	51
than 0.05 mm wide	C	4800	4800			
	D	4800	4800			
	E	5000	5000			
	F	5000	4900			

* The impact hammer does not give an absolute value for the strength of the concrete. It actually gives a relative strength value, based on the surface concrete, that can be used for comparison purposes.

** Ultrasonic Pulse Velocity Readings, identified from A to F, were taken north-south (N-S) or east-west (E-W) through the columns.

TABLE 8 (CONT'D)
PICKERING NGS 1990 OUTAGE
VACUUM BUILDING - COLUMNS IN EWST
NONDESTRUCTIVE TEST DATA

LOCATION	ULTRASONIC PULSE VELOCITY READINGS (m/s)**			IMPACT HAMMER READINGS*		
				AVERAGE REBOUND NUMBER		RELATIVE STRENGTH (MPa)
Col G7	Reading	NE-SW	NW-SE			
- readings taken in 1980	A	4800	-		45.5	43
	B	4800	-			
	C	4800	-			
	D	4800	-			
	E	4800	-			
	F	4800	-			
Col G11		NE-SW	NW-SE			
- readings taken in 1990	A	5000	5000	Southeast	52.2	54
	B	4900	4900	Northwest	53.0	55
	C	4800	4800			
	D	4900	5000			
	E	4900	5000			
	F	5000	5000			
		NE-SW	NW-SE			
- readings taken in 1980	A	4800	-		49.7	50
	B	4800	-			
	C	4800	-			
	D	4800	-			
	E	4800	-			
	F	4800	-			
Col J6		NE-SW	NW-SE			
- readings taken in 1990	A	4700	4800	East	50.2	50
- vertical hairline cracks less	B	4700	4700	West	51.2	52
than 0.05 mm wide	C	4600	4600			
	D	4600	4600			
	E	4700	4600			
	F	4800	4800			

* The impact hammer does not give an absolute value for the strength of the concrete. It actually gives a relative strength value, based on the surface concrete, that can be used for comparison purposes.

** Ultrasonic Pulse Velocity Readings, identified from A to F, were taken northeast-southwest (NE-SW) or northwest-southeast (NW-SE) through the columns.

TABLE 9
PICKERING NGS 1990 OUTAGE
VACUUM BUILDING - BEAMS IN EWST
NONDESTRUCTIVE TEST DATA

BEAM LOCATION	ULTRASONIC PULSE VELOCITY READINGS (m/s)**				IMPACT HAMMER READINGS*	
					AVERAGE REBOUND NUMBER	RELATIVE STRENGTH (MPa)
	Reading					
Elevation 418'		A	B	C		
Beam between Cols E7 and E8	1	4700	4700	4700	North 44.6	41
- readings taken in 1990	2	4700	4700	4800	South 44.2	41
	3	4700	4700	4700		
		A	B	C		
- readings taken in 1980	1	4700	4800	4700	42.0	37
	2	4800	4800	4700		
	3	4700	4800	4700		
Beam between Cols G7 and G8		A	B	C		
- readings taken in 1990	1	4700	4800	4800	North 44.3	41
	2	4800	4800	4700	South 43.4	39
	3	4900	4800	4900		
		A	B	C		
- readings taken in 1980	1	4800	4800	4800	40.8	36
	2	4800	4700	4700		
	3	4900	4800	4800		
Beam between Cols G7 and F7		A	B	C		
- readings taken in 1990	1	4900	4900	4700	East 42.6	38
	2	4800	4800	4700	West 42.9	39
	3	4800	4800	4800		
		A	B	C		
- readings taken in 1980	1	4800	4800	4800	41.4	37
	2	4800	4700	4700		
	3	4900	4800	4800		
Beam between Cols H8 and J8		A	B	C		
- readings taken in 1990	1	4800	4700	4700	East 45.9	43
	2	4600	4700	4700	West 42.4	37
	3	4800	4800	4800		
Beam between Cols H6 and J6		A	B	C		
- readings taken in 1990	1	4700	4700	4600	East 43.1	39
	2	4600	4600	4700	West 45.6	43
	3	4700	4700	4800		

* The impact hammer does not give an absolute value for the strength of the concrete. It actually gives a relative strength value, based on the surface concrete, that can be used for comparison purposes.

** Ultrasonic Pulse Velocity Readings were taken on a grid identified 1 to 3 and A to C.

TABLE 10
PICKERING NGS 1990 OUTAGE
VACUUM BUILDING - EXTERIOR OF ROOF SLAB
NONDESTRUCTIVE TEST DATA

LOCATION	ULTRASONIC PULSE VELOCITY READINGS (m/s)	IMPACT HAMMER READINGS*	
		AVERAGE REBOUND NUMBER	RELATIVE STRENGTH (MPa)
Crack in slab east of east upper chamber - width 1.0 mm at surface	Sound concrete 4400 m/s Estimated depth of crack A 60 mm B 60 mm C 0 D 60 mm	48.4	52
Crack in slab near northwest hatch	Sound concrete 4300 m/s Estimated depth of crack A 30 mm B 60 mm C 50 mm	47.1	50
Repaired crack in edge of southeast portion of slab (near Crack 36)	Sound concrete 4300 m/s Estimated depth of crack A 160 mm B 80 mm C 140 mm D 120 mm	-	-

* The impact hammer does not give an absolute value for the strength of the concrete. It actually gives a relative strength value, based on the surface concrete, that can be use for comparison purposes.

TABLE 10
PICKERING NGS 1990 OUTAGE
VACUUM BUILDING - EXTERIOR OF ROOF SLAB
NONDESTRUCTIVE TEST DATA

LOCATION	ULTRASONIC PULSE VELOCITY READINGS (m/s)
Repaired crack in edge of east portion of slab (between Cracks 52 and 53) - see Figure 25	Sound concrete 4000 m/s Estimated depth of crack A 0 B 0 C 130 mm D 0
Repaired crack in edge of north portion of slab (between Cracks 6 and 7)	Sound concrete 4500 m/s Estimated depth of crack A 160 mm B 140 mm C 140 mm D 100 mm
Repaired crack in edge of west portion of slab (near Crack 3)	Sound concrete 4000 m/s Estimated depth of crack A 160 mm B 160 mm C 110 mm D 70 mm

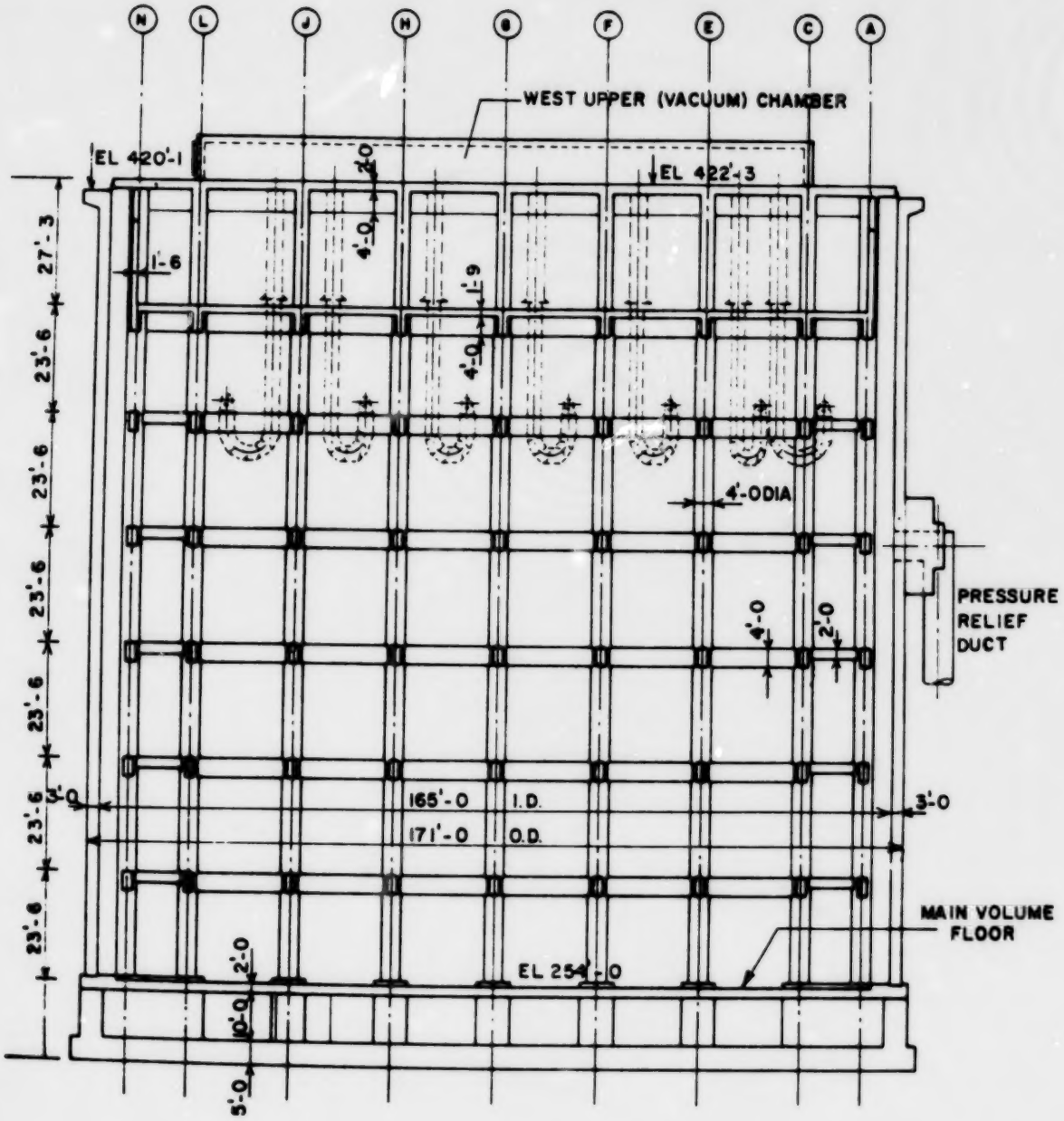


Figure A

Pickering NGS
Vacuum Building
Section Through Column Line 7

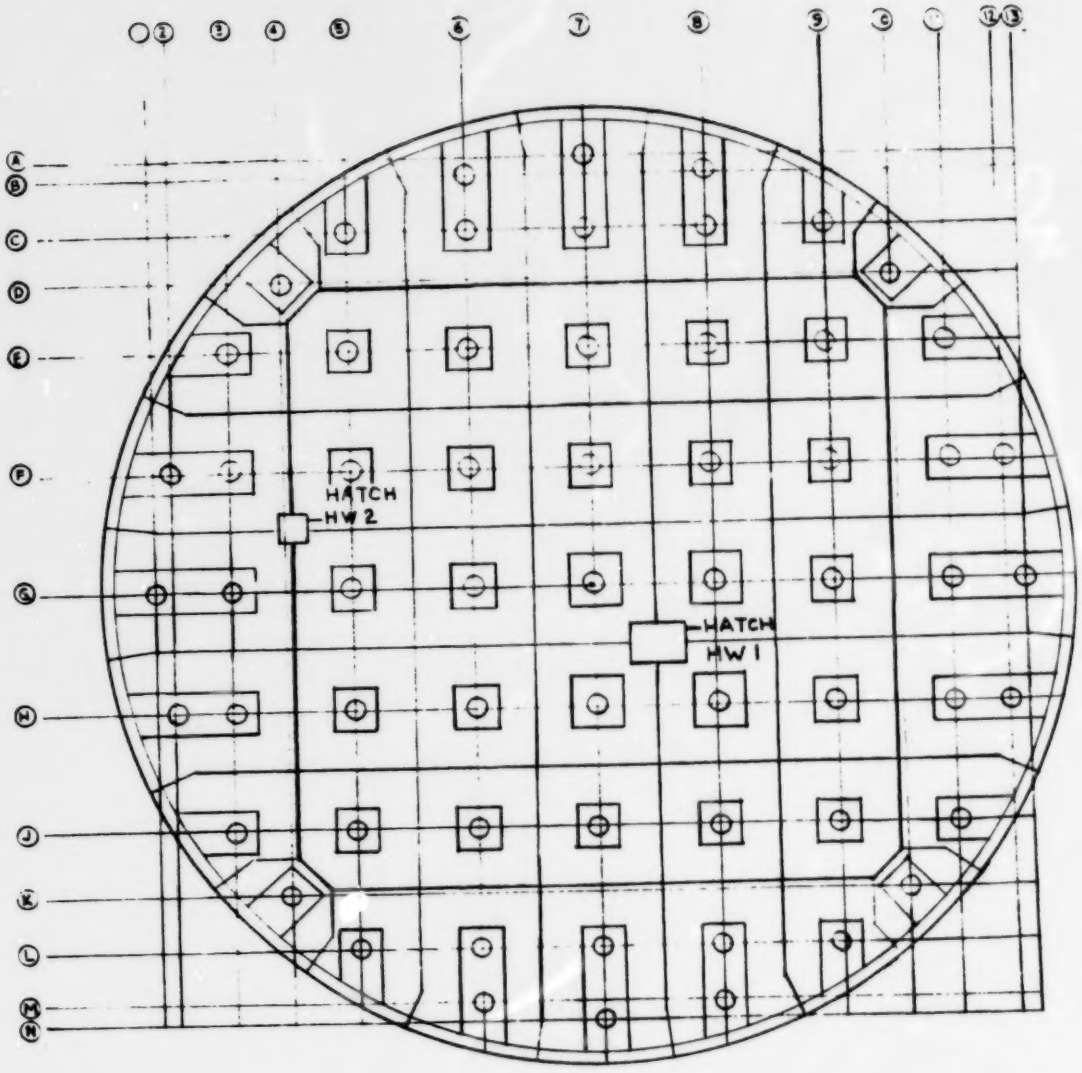


Figure B

Pickering NGS
Vacuum Building
Plan View at Elevation 254'

Figure 1 - Strain gauges on the underside of the Vacuum Building floor slab west of Col J8. Shown here are Pfender Gauge 1, Full Bridge Gauge 6 (attached to the reinforcing steel) and Quarter Bridge Gauges 3 and 4 (attached to the concrete surface). See Appendix A for identification of the strain gauges.

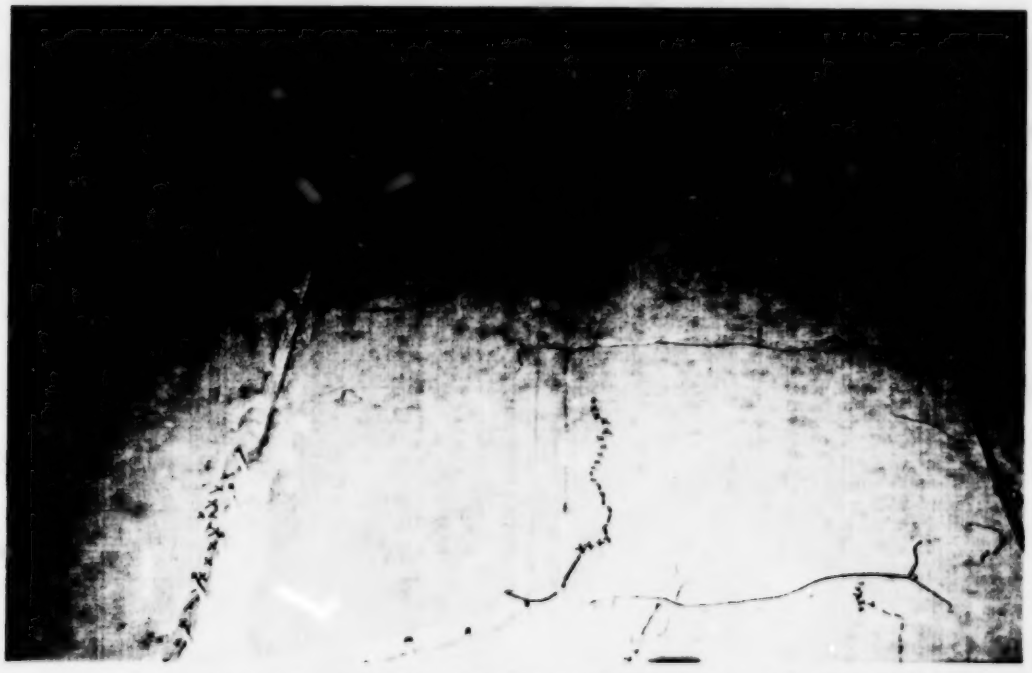


Figure 2 - Crack mapping on the underside of the Vacuum Building floor slab. The solid, dotted and crossed lines represent hairline cracks observed during operation, when the building was at atmospheric pressure and immediately after the douse test, respectively.

Figure 3 - Crack through a repair noted after the douse test. This area is shown in the lower left corner of Figure 1.

Figure 4 - Leakage observed after the douse test at the unrepaired west side of Col G11.

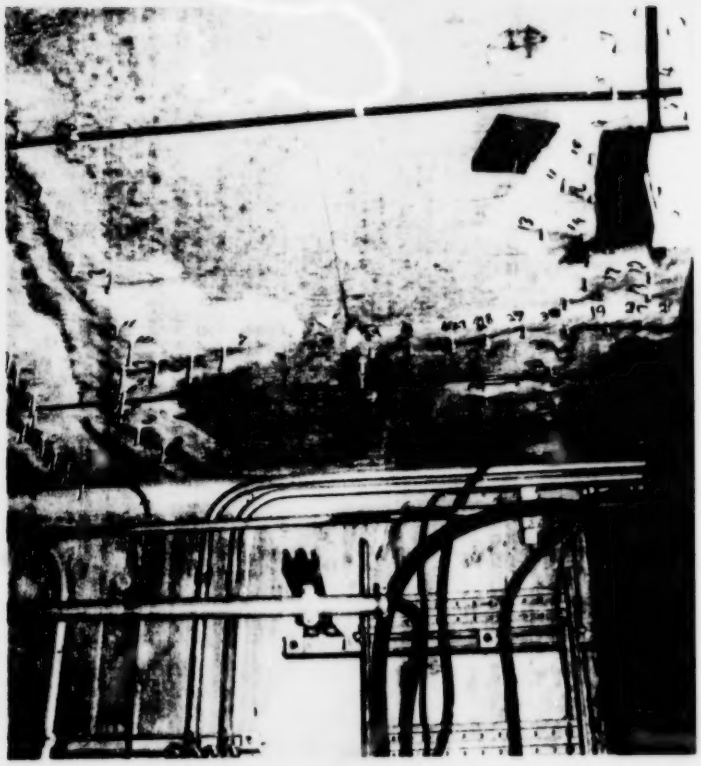


Figure 5 - Leakage observed after the douse test to the west of Col G9 at the extension of a repaired crack.

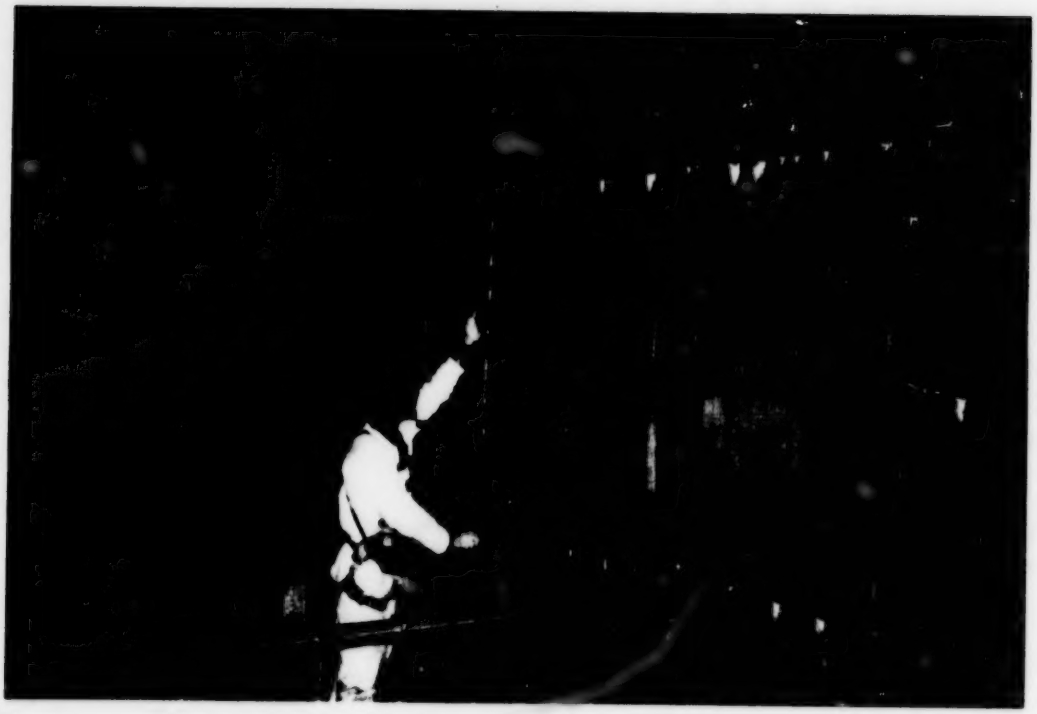


Figure 6 - Horizontal cracks with efflorescence at Elevation 371.5' (crack width 0.10 to 0.13 mm).

Figure 7 - Col F12, as viewed from Elevation 254'. Note the efflorescence on the column associated with cracks up to 0.30 mm wide.

Figure 8 - Crack in Col B8 with a width of 0.25 mm.

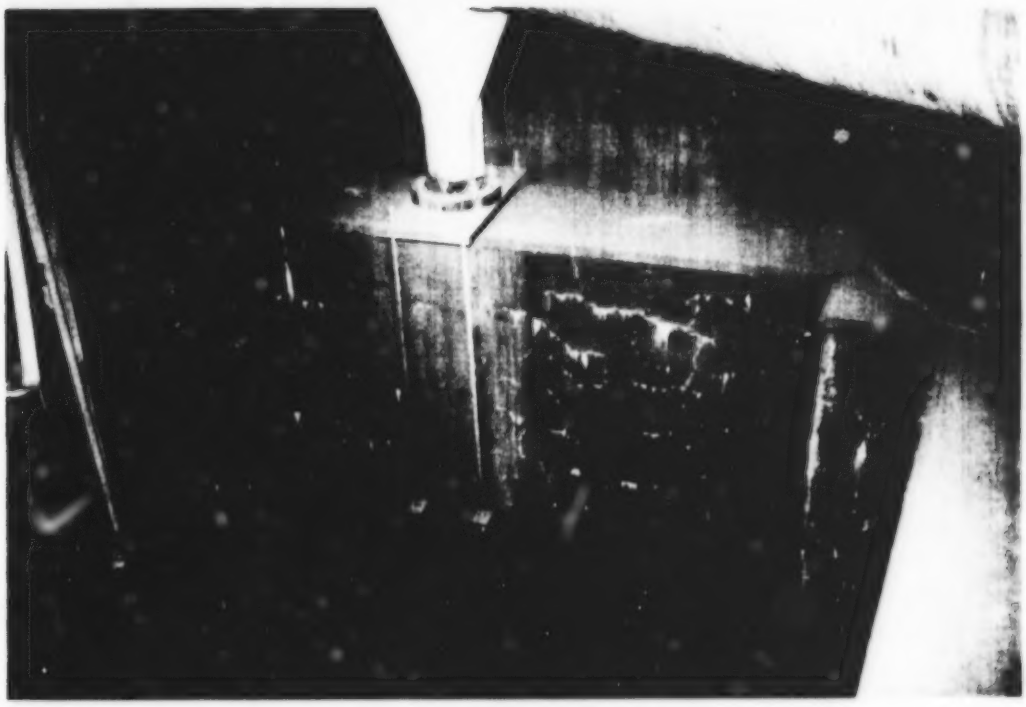


Figure 9 - Typical cracking in a beam between Cols D4 and E3 at Elevation 371.5'. Similar cracking was also observed in some of the perimeter beams at Elevation 277.5'.

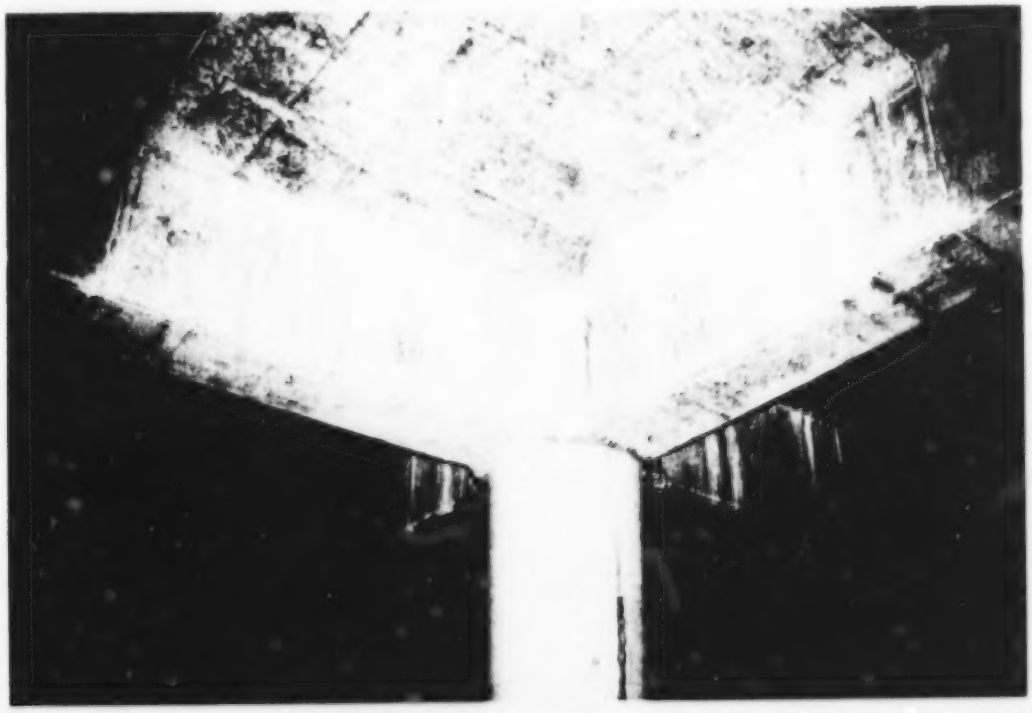


Figure 10 - Efflorescence associated with leakage through the concrete around Col G7 on the underside of the EWST floor slab.

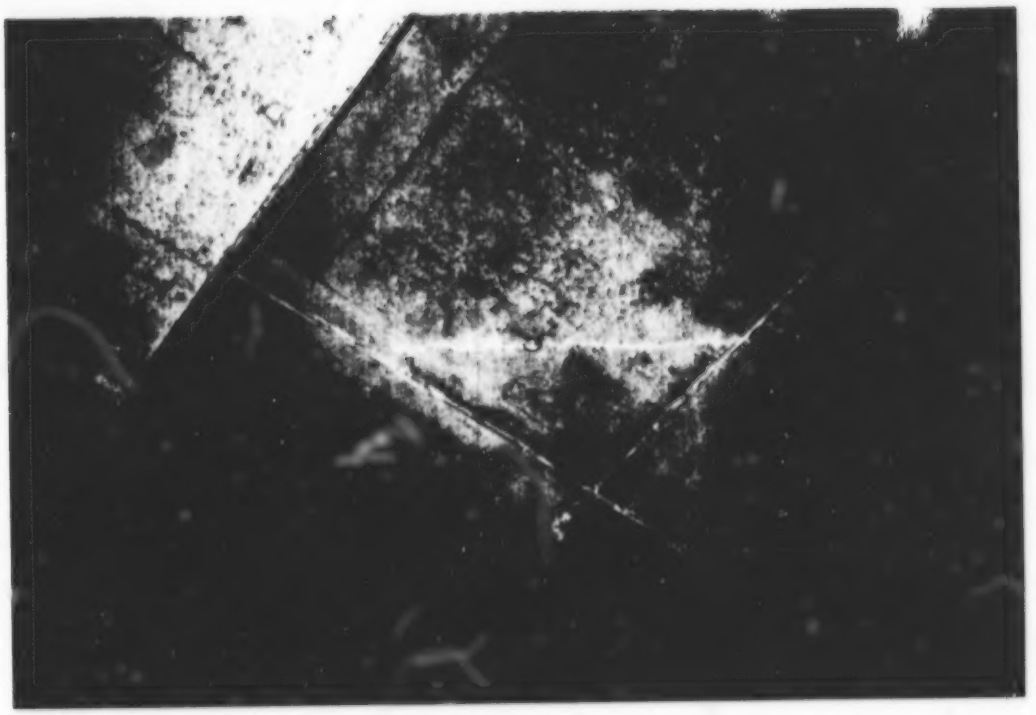


Figure 11 - Efflorescence along a crack northwest of Col H7 on the underside of the EWST floor slab.

Figure 12 - Cracks exhibiting efflorescence adjacent to Col H3 on the underside of the roof of the Vacuum Building.

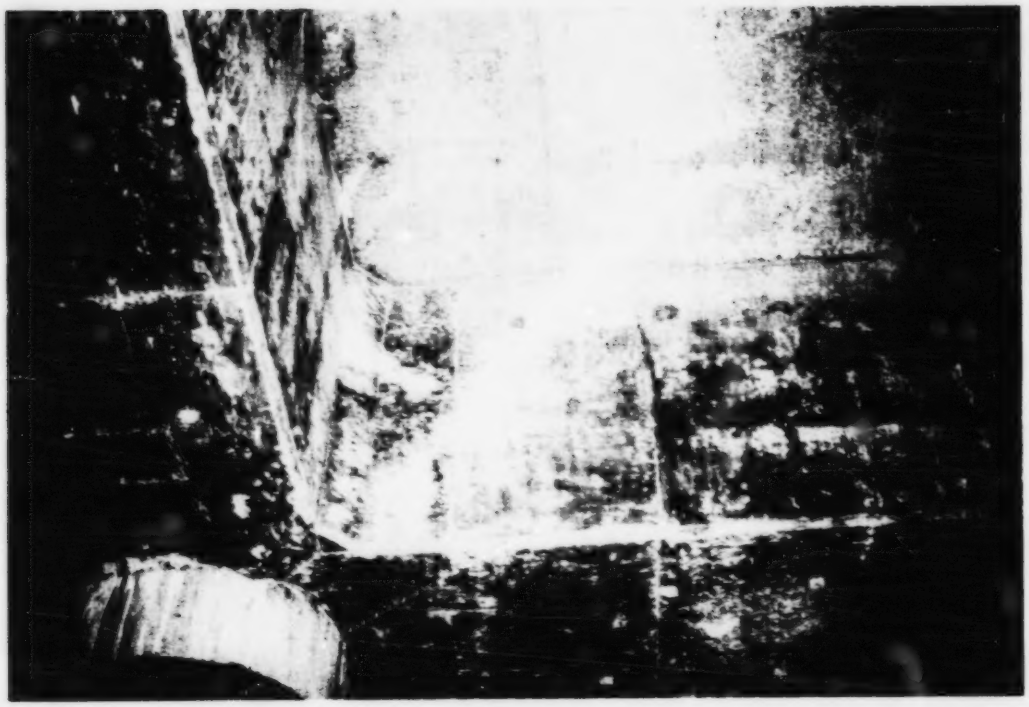


Figure 13 - Crack exhibiting efflorescence adjacent to Col F11 on the underside of the roof of the Vacuum Building.

Figure 14 - Corrosion of spiral reinforcing steel as a result of insufficient concrete cover in Col E5 in the EWST. This area was repaired by removing the surrounding concrete and replacing it with sand filled epoxy mortar.

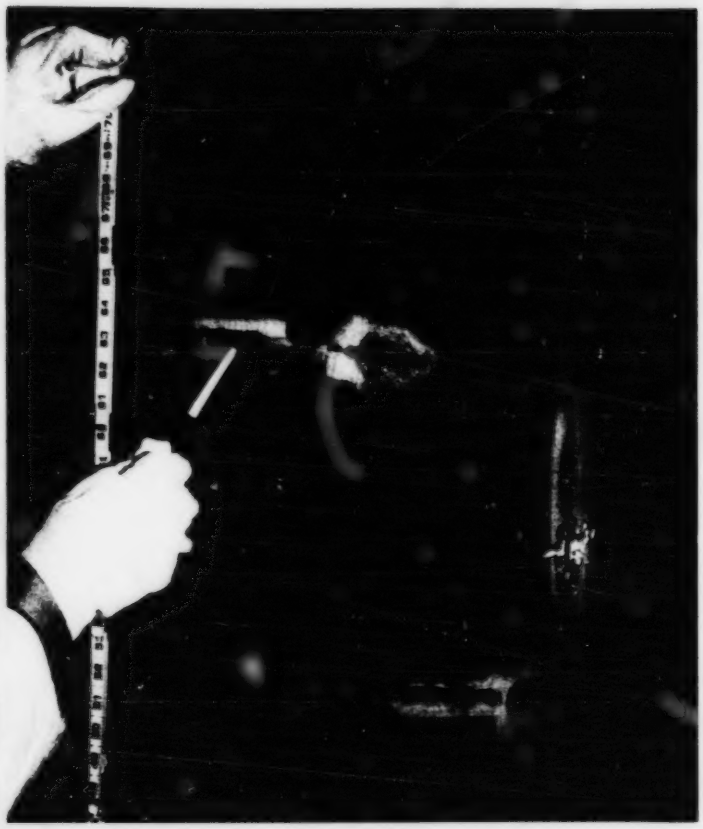


Figure 15 - Corrosion of spiral reinforcing steel as a result of insufficient concrete cover in Col G9 in the EWST. This area was repaired as was Cols E5, G6 and L7.

Figure 16 - The honeycombed concrete at the base of Col E3 in the EWST was removed and the area repaired. Note the good condition of the reinforcing steel at this location, showing no evidence of corrosion.

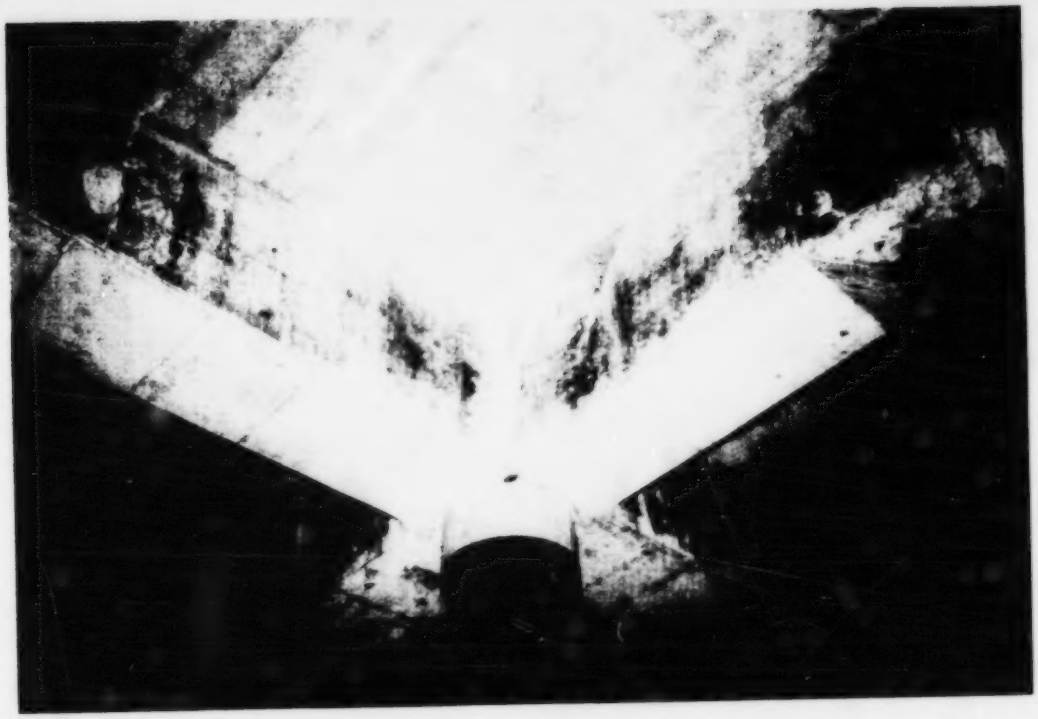


Figure 17 - A view of Col G7 from the northwest, showing the locations of nondestructive testing through the beams. Only a few hairline cracks were noted in these beams.

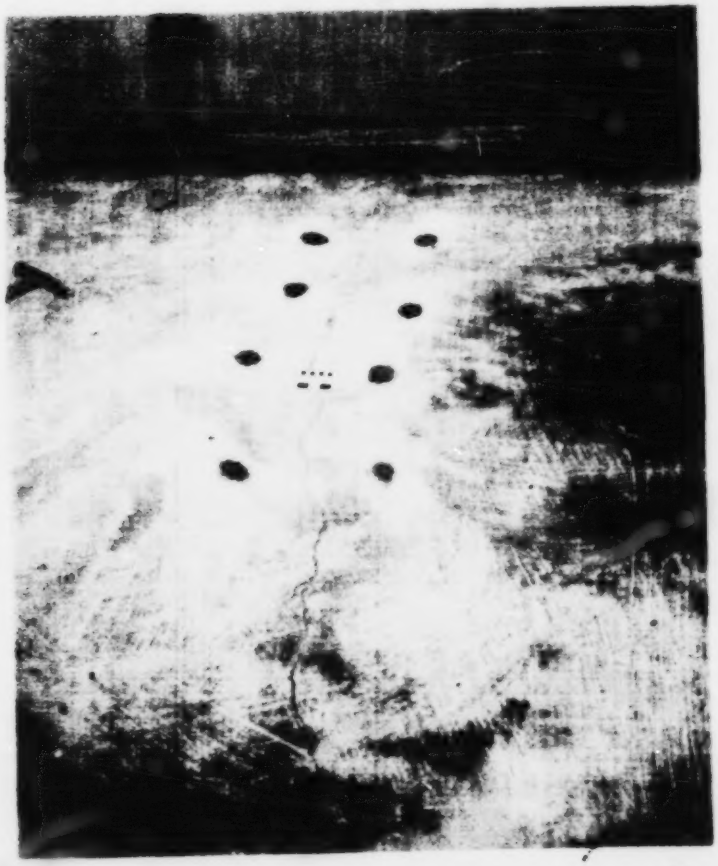


Figure 18 - A crack in the roof slab of the Vacuum Building, which was evaluated nondestructively (width 1.0 mm at the surface). Because of the presence of material in the crack, the depth could not be estimated.

Figure 19 - Repairs made previously to cracks in the edge of the Vacuum Building roof slab above the roof seal.

Figure 20 - Popout on the exterior surface of the upper chamber as a result of a corroded steel tie rod near the surface of the concrete.

APPENDIX A

Pickering NGS 1990 Outage
Vacuum Building
Strain Gauge Readings

Pickering NGS 1990
Vacuum Building
Strain Gauge Readings

The monitoring of the strain gauges installed in 1980 and the ones installed during this inspection are summarized below.

Electronic Gauges installed in 1980.

(a) Three gauges, attached to the surface of the building in the north quadrant, were found not to be operating and were removed.

(b) Two full bridge strain gauges, attached to reinforcing steel on the underside of the floor slab (Full Bridge 5 midway between Cols J7, J8, H7 and H8 and Full Bridge 6 west of Col J8), were monitored. The results obtained from Full Bridge 5, during the douse test, are given in Figure A1. The results obtained from Full Bridge 6 appeared to be in error and have not been reported.

Pfender Gauges installed in 1980.

(c) Three Pfender gauges (7 to 9), attached to the surface of the building in the north quadrant, were monitored during the inspection. Due to equipment problems these gauges were not monitored after the douse test. The results are plotted in Figure A3.

(d) Six Pfender gauges (1 to 6), attached to the underside of the main floor slab in the vicinity of the strain gauges reported in (b) above, were monitored during the inspection. The results are plotted in Figure A3.

Electronic Gauges installed in 1990.

(e) Three quarter bridge strain gauges were installed on the surface of the building in the north quadrant to monitor the strains experienced by the wall during the douse test. These gauges did not identify any strains during the test and the results have therefore not been reported. The lack of strains indicated by the gauges may reflect the lack of strain experienced by the wall or the gauges may not have been operating properly.

(f) Four quarter bridge gauges were installed on the underside of the main floor slab in the vicinity of the gauges reported in (b) above (Quarter Bridge 1 and 2 near Full Bridge 5 and Quarter Bridge 3 and 4 near Full Bridge 6). During the douse test these gauges were monitored at half second intervals. The results have been plotted in Figures A1 and A2.

FIGURE A1

PICKERING NGS 1990 OUTAGE
UNDERSIDE OF VACUUM BUILDING MAIN FLOOR SLAB
STRAIN MEASUREMENTS DURING DOUSE TEST
(Gauges Between Cols J7, J8, H7 and H8)

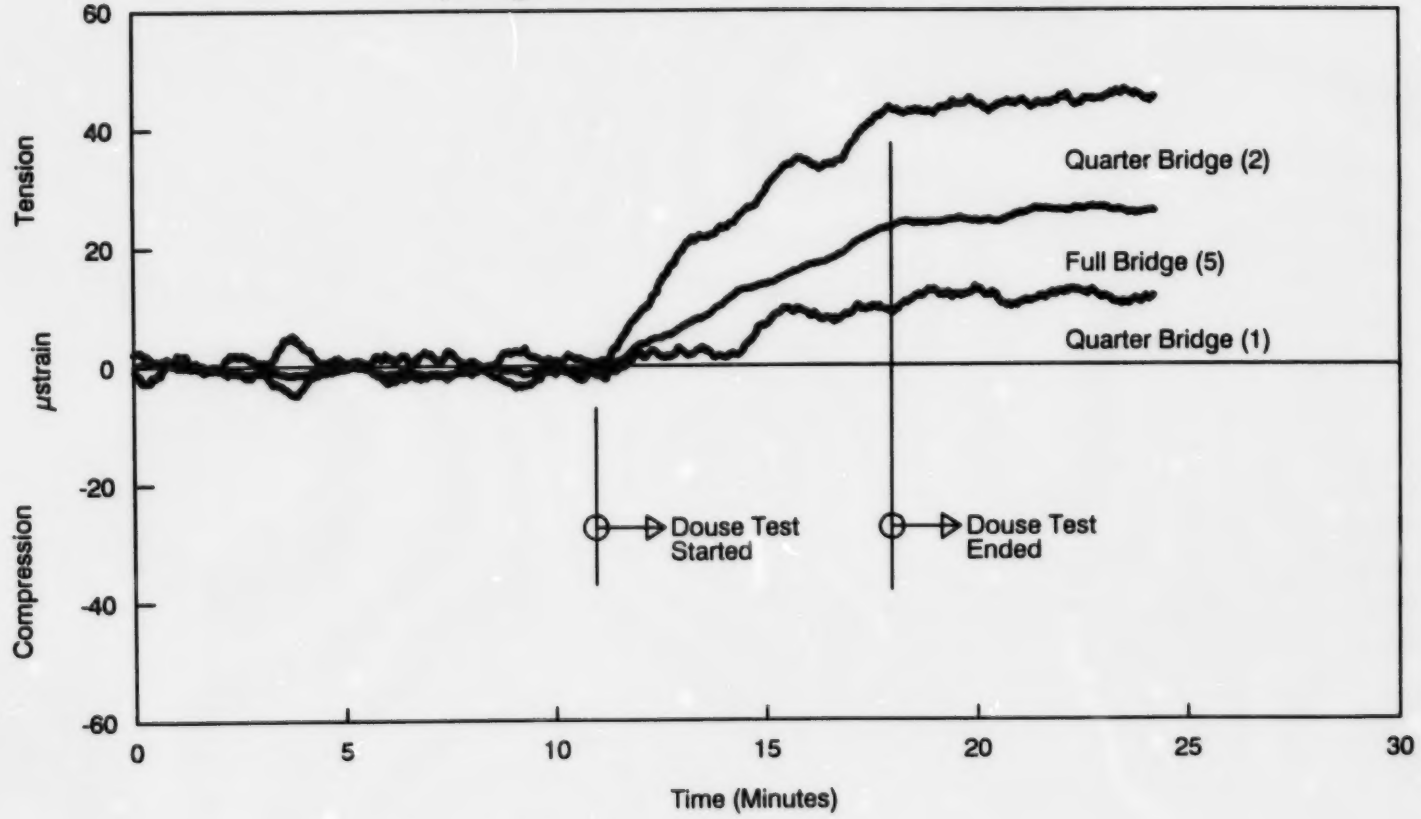


FIGURE A2

PICKERING NGS 1990 OUTAGE
UNDERSIDE OF VACUUM BUILDING MAIN FLOOR SLAB
STRAIN MEASUREMENTS DURING DOUSE TEST
(Gauges West of Col J8)

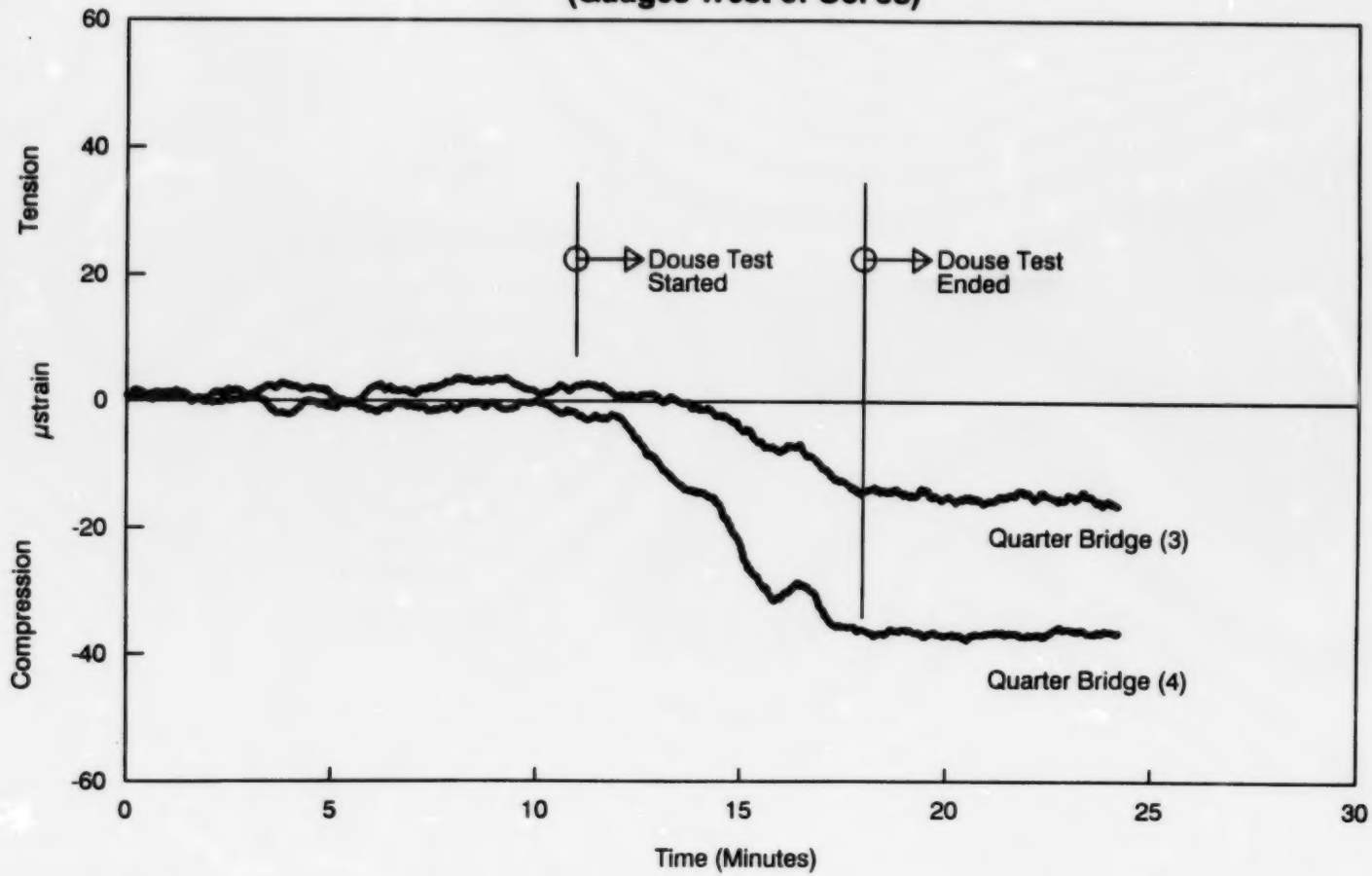
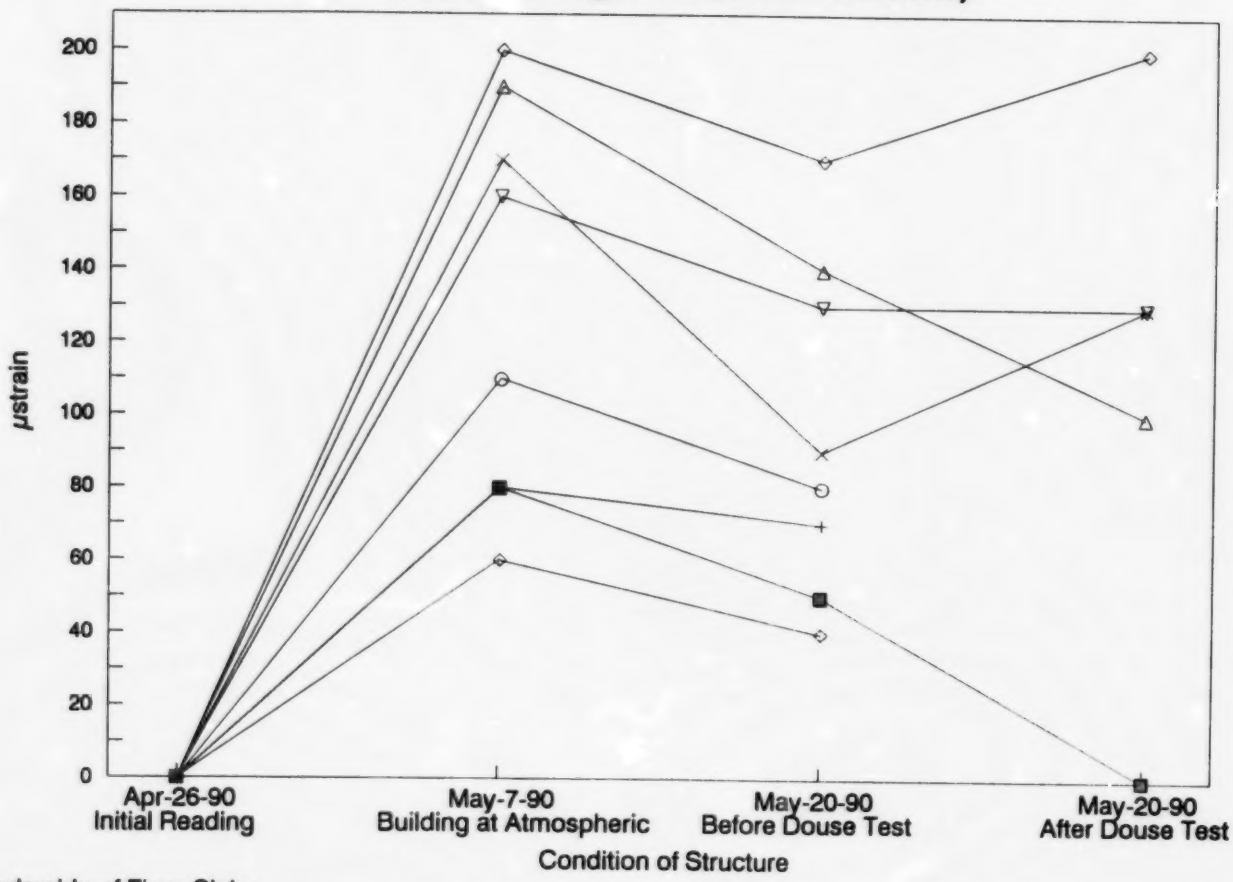


FIGURE A3

PICKERING NGS 1990 OUTAGE
STRAIN MEASUREMENTS DURING INSPECTION
(Pfender Gauges at Various Locations)



Underside of Floor Slab :
■ Pfender 1 ◇ Pfender 3 △ Pfender 4 × Pfender 5 ▽ Pfender 6

Perimeter Wall :
○ Pfender 7 + Pfender 8 ◇ Pfender 9

NOTE: Pfender 2, on the underside of the main slab, was not accessible

APPENDIX B

Pickering NGS 1990 Outage
Vacuum Building
Concrete Core Log

APPENDIX B

Pickering NGS 1990 Outage
Vacuum Building
Main Floor Slab
Concrete Core Log

A total of 11 cores (70 mm diameter) were drilled from the main floor slab in the vicinity of Col E6, to obtain specimens for laboratory testing and to expose reinforcing steel for visual inspection. The location and a photo of the cores are given in Figures B1 and B2 and the results of laboratory tests are given below. All holes were repaired after drilling.

Laboratory Test Results (see Notes)							
Core No.	Location x mm	Location y mm	Length of Core mm	Density kg/m^3	Absrp %	Comp. Strength MPa	Ultrasonic Pulse Velocity m/s	Remarks
E61	1020	1800	190	2388	-	37.0	4660	
E62	1140	1800	175	2392	-	34.7	4690	
E63	1240	1930	180	2356	-	36.0	4690	
E64	1350	1980	180	2403	-	34.1	4860	
E65	1140	580	160	2358	-	37.0	4570	
E66	3560	1570	155	2372	-	34.8	4690	- reinforcing steel was exposed at the bottom of this hole
E6	1140	580	90	2367	5.0	-	-	- four cores were drilled from this location - test results are the average of four specimens
Avg	-	-	-	2377	5.0	35.6	4690	

Notes:

1. The density of saturated surface dry (SSD) specimen was measured.

2. The absorption after 48 hours immersion was measured as per ASTM C 642.

3. The compressive strength was measured on SSD specimens as per CAN/CSA-A23.2-14C. All specimens had a length to diameter ratio after capping of approximately 2.

4. The ultrasonic pulse velocity readings were obtained on the compressive strength specimens prior to capping.

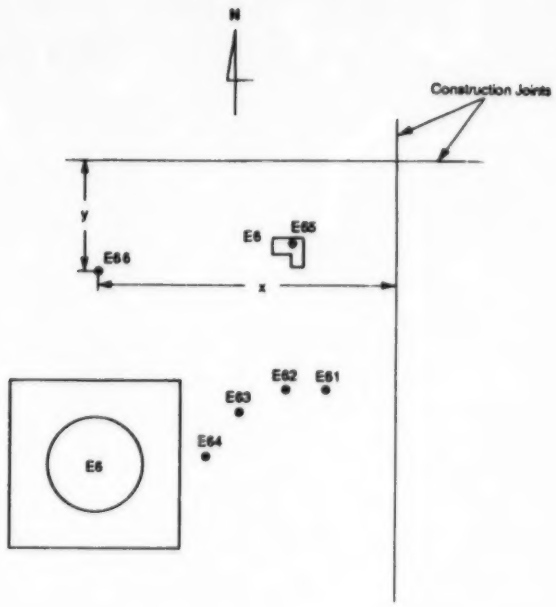


Figure B1 Location of the core holes in the main floor slab near Col E6 at Elevation 254'.

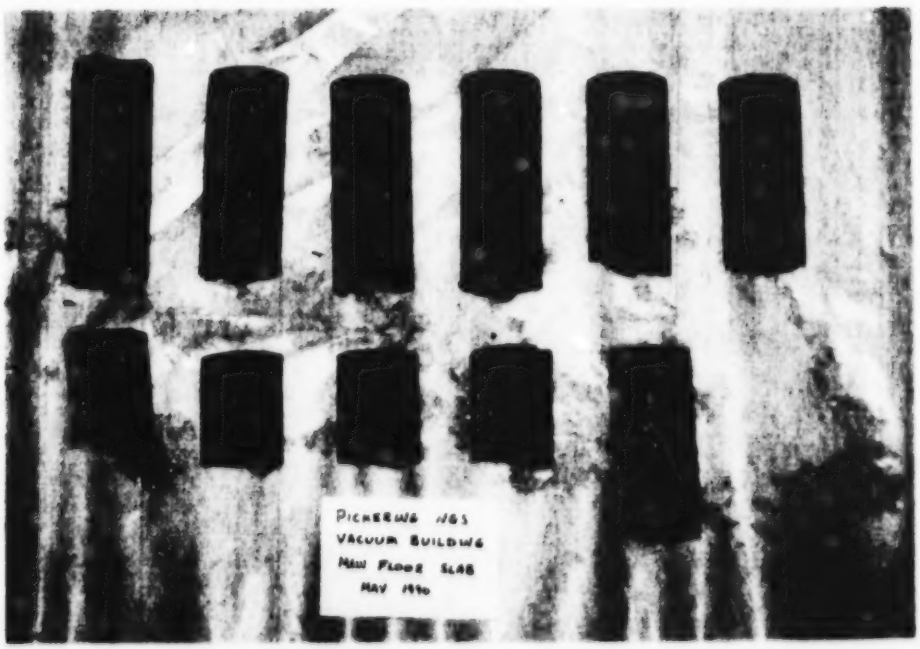


Figure B2 The cores drilled from the floor slab at Elevation 254' in the vicinity of Col E6. Core E6-A was not tested.

Pickering NGS 1990 Outage
Vacuum Building
EWST Floor Slab
Concrete Core Log

Eight cores (70 mm diameter) were drilled from the floor slab of the EWST. Cores EWST 1 to 3 were drilled in the vicinity of Col H5. At this location reinforcing steel was exposed however the cores were inadvertently discarded. The remaining cores were drilled in the vicinity of Col F9, where reinforcing steel was exposed in one core.

The location and photo of the cores is given in Figures B3 to B5 and the results of the laboratory tests are given below.

Laboratory Test Results (see Notes)								
Core No	Location x mm	Location y mm	Length mm	Density kg/m^3	Absrp %	Comp Strength MPa	Ultrasonic Pulse Velocity m/s	Remarks
EWST 1	1070	150	-	-	-	-	-	- core inadvertently discarded - reinforcing steel exposed
EWST 2	1180	240	-	-	-	-	-	- core inadvertently discarded
EWST 3	930	250	-	-	-	-	-	- core inadvertently discarded
EWST 4	1050	7010	120	2345	4.8	-	-	
EWST 5	1170	7090	80	2391	4.7	-	-	
EWST 6	1260	6990	185	2348	-	32.4	4500	
EWST 7	1570	6990	130	2353	-	33.1	4520	- reinforcing steel exposed
EWST 8	1700	6990	145	2336	-	33.5	4480	
AVG	-		-	2355	4.8	33.7	4500	

Notes:

1. The density of saturated surface dry (SSD) specimens was measured.

2. The absorption after 48 hours immersion was measured as per ASTM C 642.

3. The compressive strength was measured on SSD specimens as per CAN/CSA-A23.2-14C. The specimens had a length to diameter ratio after capping of 2, otherwise corrections factors were applied to the test results.

4. The ultrasonic pulse velocity readings were obtained on the compressive strength specimens prior to capping.

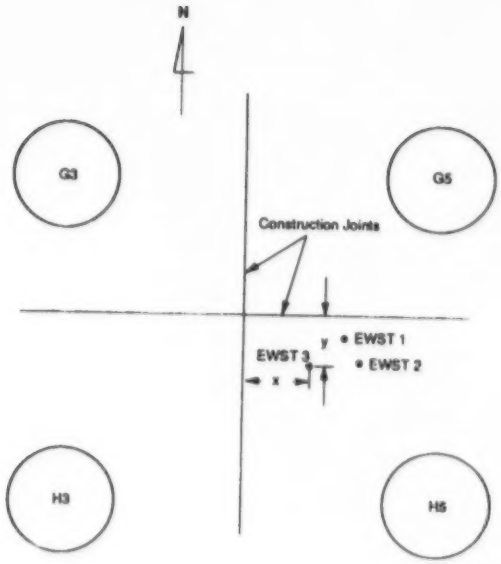


Figure B3 Location of cores drilled from the floor slab of the EWST in the vicinity of Col H5. The cores from these locations were inadvertently discarded.

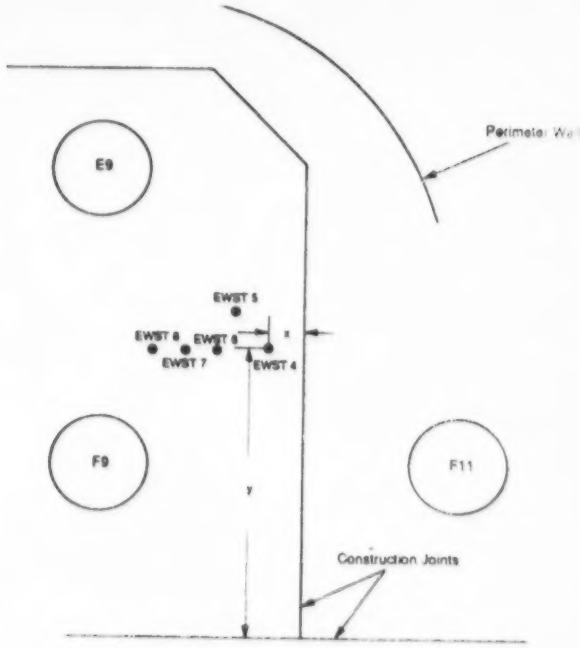


Figure B4 Location of cores drilled from the floor slab of the EWST in the vicinity Col H9.

Figure B5 Cores drilled from the floor slab of the EWST in the locations shown in Figure B4. Cores are numbered from left to right EWST 4 to EWST 8, respectively.

APPENDIX C

Pickering NGS 1990 Outage
Vacuum Building
Half-Cell Potential Measurements of Reinforcing Steel

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ontario hydro
research division

TO: Mr. H. Caratin
Concrete Technology Section
Civil Research Department

ESTIMATION OF THE CORROSION ACTIVITY OF THE REINFORCING STEEL IN CONCRETE DURING THE 1990 VACUUM BUILDING OUTAGE AT PICKERING NGS A AND B

A.C. Headon

The electrical half cell potentials of the reinforcing steel were measured at two locations in the Main Volume floor (EL 254'-0") and two locations in the Emergency Water Storage Tank floor (EL 395'-0"). The potentials indicated that there was a greater than 90% probability that no reinforcing steel corrosion was occurring at the time of measurement. Columns E5 and G9 in the EWST had localized areas of visibly corroding reinforcing steel exposed. Electrical half cell potentials indicated that the reinforcing steel was also corroding at nearby areas in these columns. The potentials of the reinforcing steel of two columns adjacent to E5 and eight columns adjacent to G9 indicated a greater than 90% probability that no corrosion of their reinforcing was occurring.

INTRODUCTION

This corrosion survey was conducted at the request of Mr. H. Caratin of the Civil Research Department and will be included as an Appendix to his report on the internal inspection of the Vacuum Building.

The measurement of the corrosion activity of the reinforcing steel was requested at two locations in the Main Volume floor (EL 254'-0"), two locations in the Emergency Water Storage Tank floor (EL 395'-0"). As columns E5 and G9 in the EWST had visibly corroding reinforcing steel exposed, these columns and two adjacent to E5 and eight adjacent to G9 were also surveyed. (Columns G6 and L7 also had visibly corroding reinforcing steel exposed but were not surveyed.

The Standard Test Method for Half Cell Potentials of Reinforcing Steel in Concrete ANSI/ASTM C876-87 was used. This method may be used to assess the relative extent and progress of corrosion of steel embedded in concrete members. This method is applicable to members regardless of their size or the depth of concrete cover over the reinforcing steel. The results obtained by this method should not be considered as a means for estimating the structural properties of the steel or of the reinforced concrete member.

job	file	date	report no.
82-127-553	827.2	June 22, 1990	ME90-2-H

METHOD

The testing apparatus consisted of a copper-copper sulphate half cell, a digital voltmeter with an input impedance of 10MΩ, a supply of small sponges and electrical lead wires.

A grid with a spacing of 0.9 m (3 feet) was marked out on the surface of the floor where readings were to be made. The reinforcing steel was exposed by drilling in the floor slab. A direct electrical connection for the positive terminal of the digital voltmeter was made to the reinforcing steel by means of a magnet after cleaning the steel surface with a portable drill and wire cup brush. The copper-copper sulphate half cell was connected to the negative terminal of the digital voltmeter.

The surface of the concrete at each grid point was chipped with a geological hammer to remove a dielectric coating that had formed on the submerged concrete. The grid points were sprayed with a wetting solution consisting of 95 mL of liquid household detergent thoroughly mixed with 19L of potable water. Sponges soaked in the wetting solution were placed on the grid points. The copper-copper sulphate reference electrode was pressed against the wet sponges and the readings recorded.

The potentials of the reinforcing steel in the columns were measured in a similar way, except that the connection to the reinforcing steel was made at the exposed area and no grid was marked on the columns.

OBSERVATIONS

The measured half cell potentials are given in Figures 1, 2, 3, 4, 5, and 6.

INTERPRETATION OF RESULTS

This interpretation is taken from ANSI/ASTM C876-87, "Standard Test Method for Half Cell Potentials of Reinforcing Steel in Concrete".

9.1 Laboratory testing of reinforced concrete specimens indicates the following regarding the significance of the numerical values of the potentials measured. Voltages listed are referenced to the copper-copper sulfate (CSE) half cell.

9.1.1 If potentials over an area are more positive than -0.20 V CSE, there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area at the time of measurement.

9.1.2 If potentials over an area are in the range of -0.20 to -0.35 V CSE corrosion activity of the reinforcing steel in that area is uncertain.

9.1.3 If potentials over an area are more negative than -0.35 V CSE, there is a greater than 90% probability that reinforcing steel corrosion is occurring in that area at the time of measurement.

9.1.4 In laboratory tests where potentials were more negative than -0.50 V, approximately half of the specimens cracked due to corrosion activity.

9.1.5 Positive readings, if obtained, generally indicate a poor connection with the steel, insufficient moisture in the concrete, or the presence of stray currents and should not be considered valid.

CONCLUSION

All the potentials of the reinforcing steel in the floor of the Main Volume, and the floor of the Emergency Water Storage Tank were more positive than -0.20 volts CSE. This indicated that there was greater than 90% probability that no reinforcing steel corrosion was occurring at these locations at the time of measurement.

All the readings made of the reinforcing steel in columns E5 and G9 were more negative than -0.35 V CSE. This indicated that there was a greater than 90% probability that reinforcing steel corrosion was occurring at the time of measurement.

Adjacent columns to E5 and G9 had potentials that indicated that there was a greater than 90% probability that no reinforcing steel corrosion was occurring at the time of measurement.

None of the measured potentials were more negative than -0.50 V CSE. This is the potential, in laboratory tests at which approximately half of the test specimens cracked due to corrosion activity.

The survey was conducted by Miss B.I. Guest and Mr. A.C. Headon of the Metallurgical Research Department.

Approved by:

P.C. Lichtenberger
Supervising Scientist
Corrosion & Tritium
Technology Section
Metallurgical Research Dept

Prepared by:

A.C. Headon
Senior Technologist
Corrosion & Tritium
Technology Section

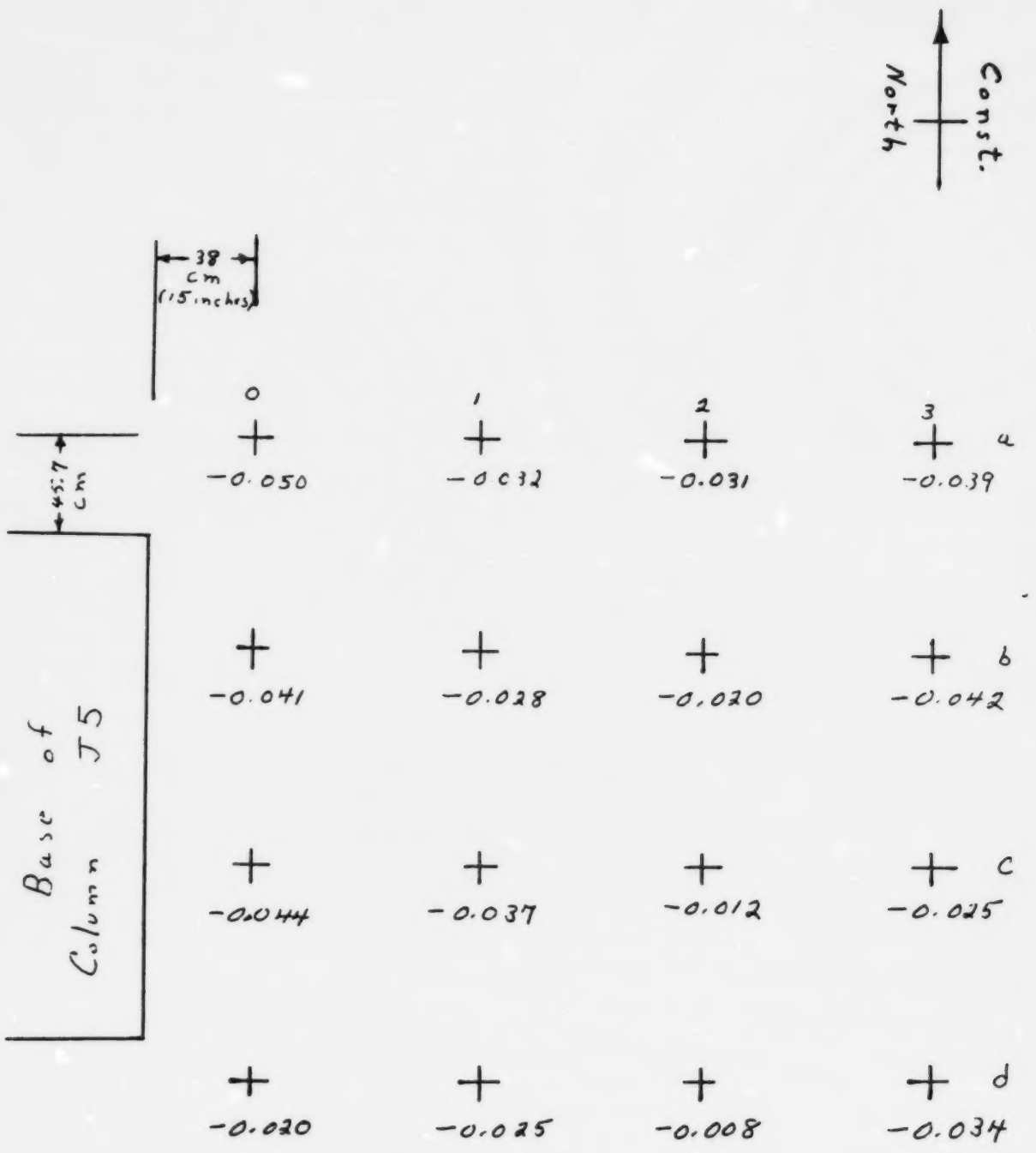


FIGURE 1

Main Volume EL 254'-0" May 1990

Readings in volts versus a $Cu/CuSO_4$ half cell.
Grid spacing 0.9 m (3 feet)

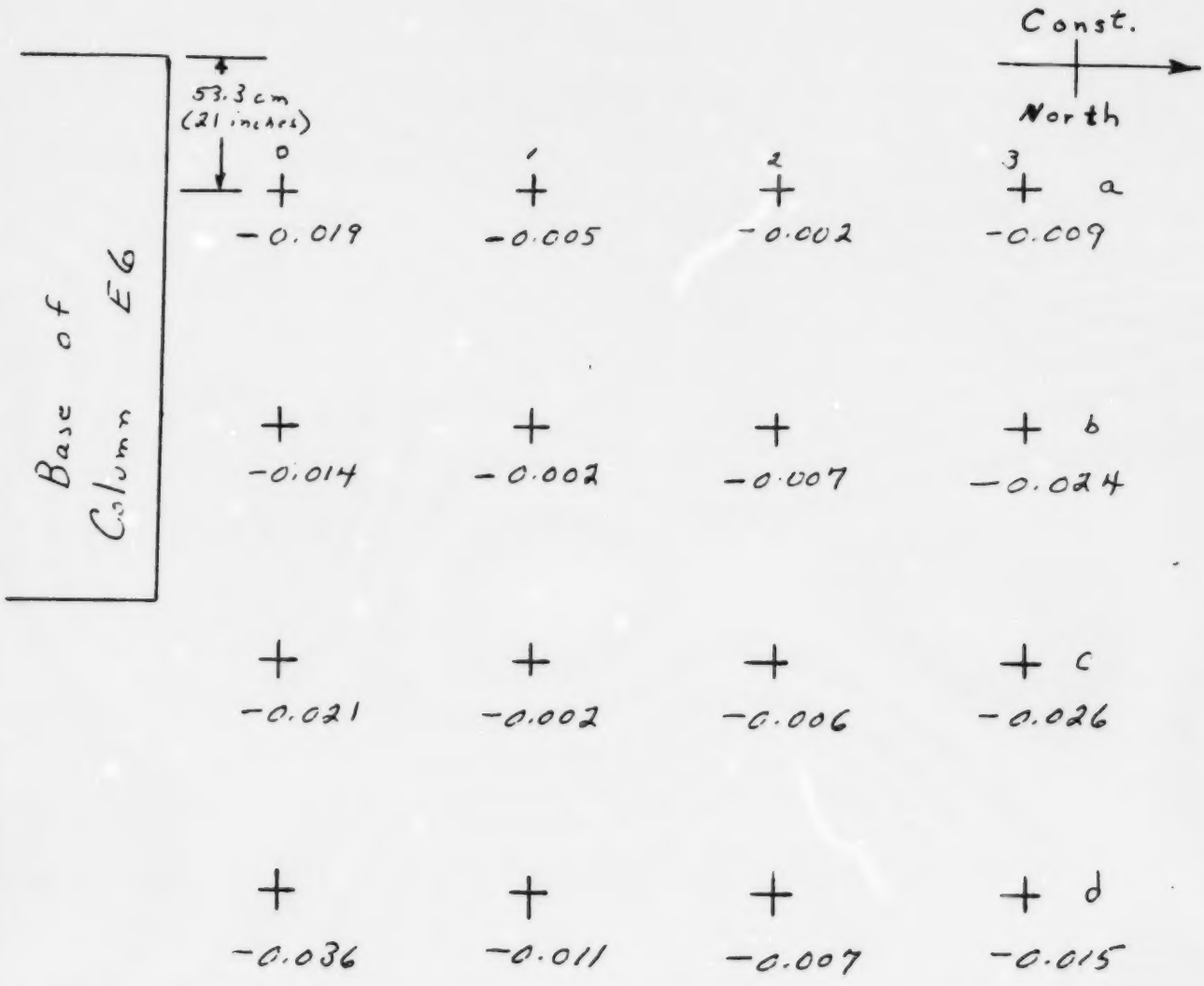


FIGURE 2

Main Volume EL 254'-0" May 1990

Readings in volts versus a $Cu/CuSO_4$ half cell.
Grid spacing 0.9 m (3 feet)

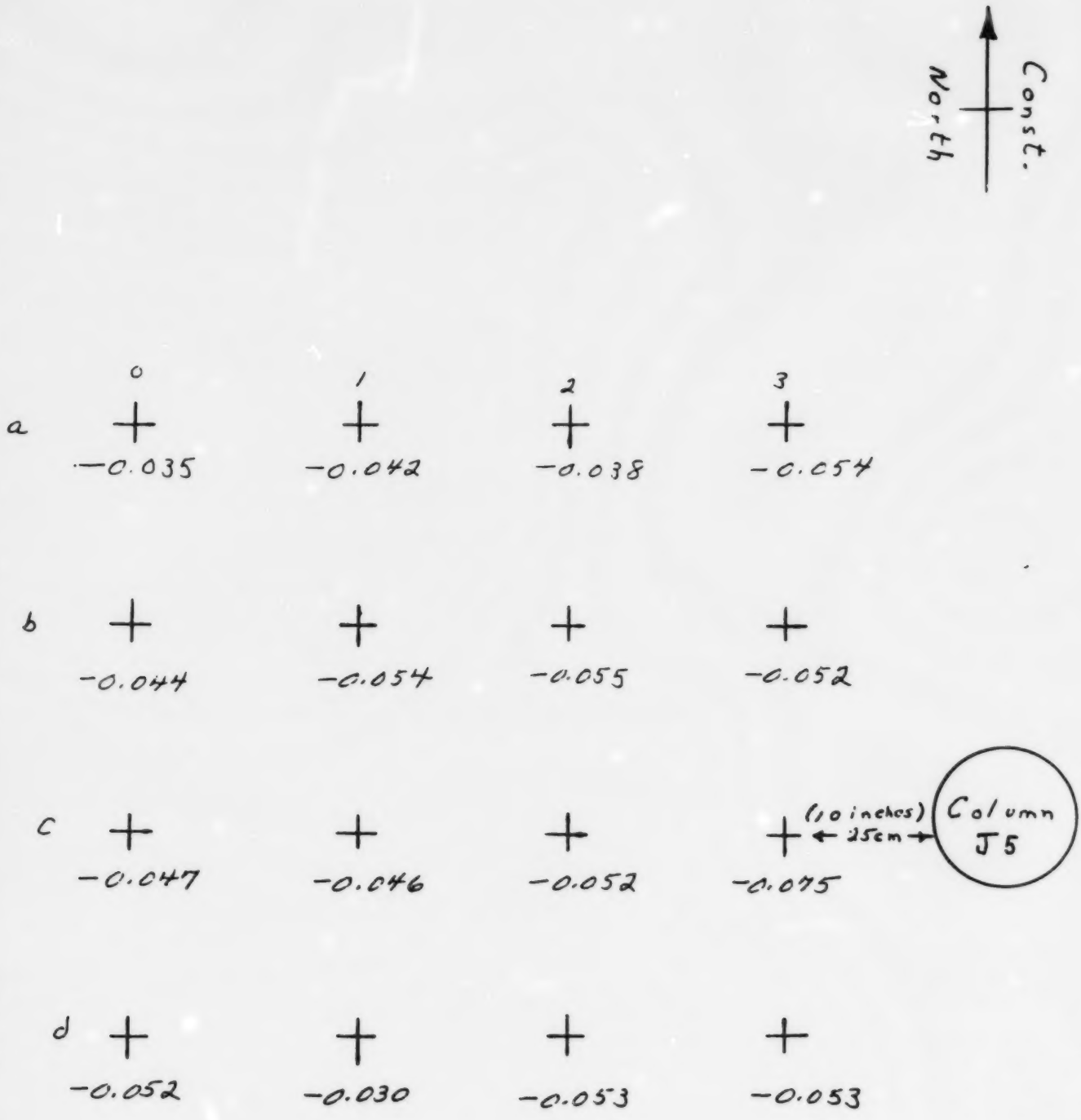


FIGURE 3

EWST EL 395'-0" May 1990

Readings in volts versus a $Cu/CuSO_4$ half cell.
Grid spacing 0.9 m (3 feet).

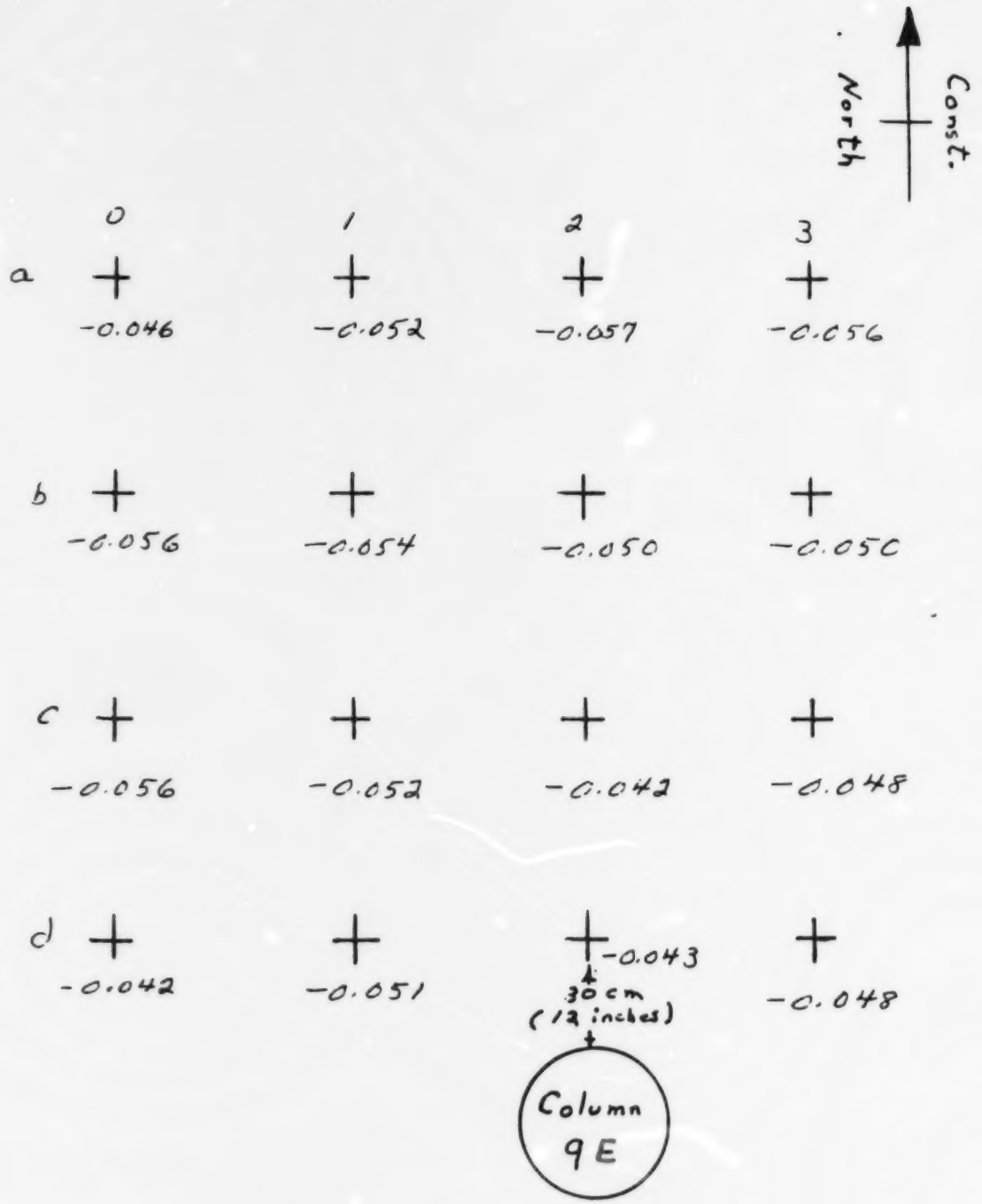
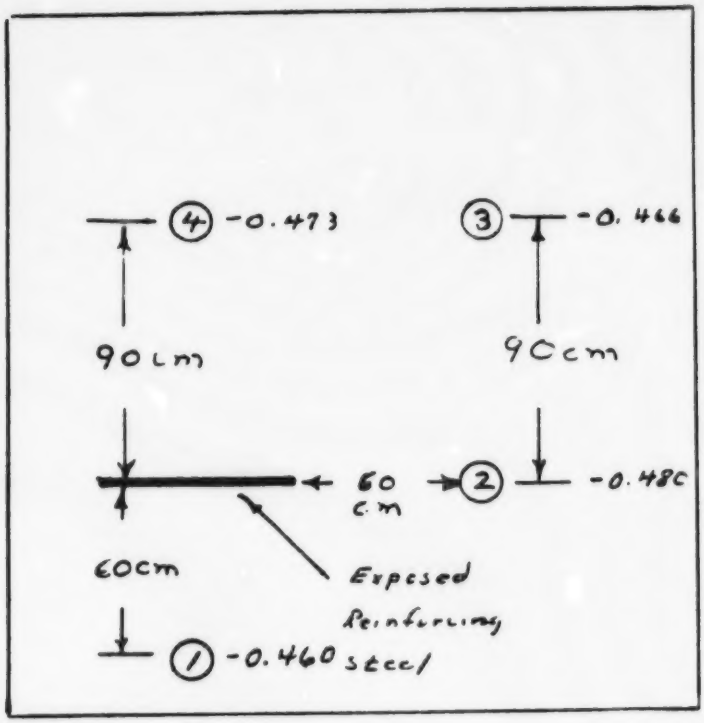
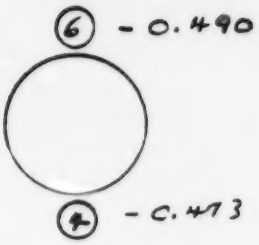


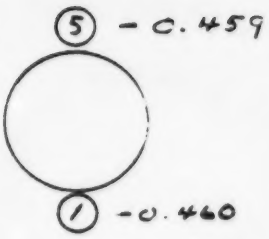
FIGURE 4

EWST EL 395'-0" May 1990

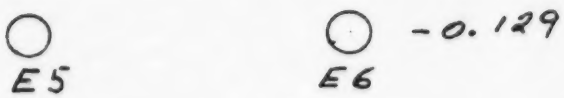
Readings in volts versus a $Cu/CuSO_4$ half cell.
Grid spacing 0.9 m (3 feet)

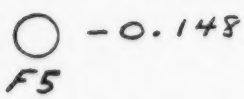






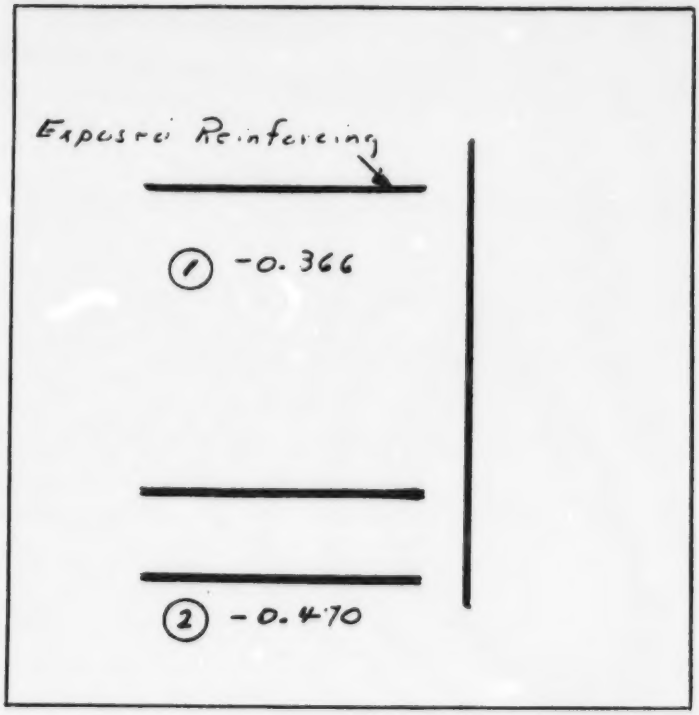
Exposed Reinforcing Rod, Column E5-EWST



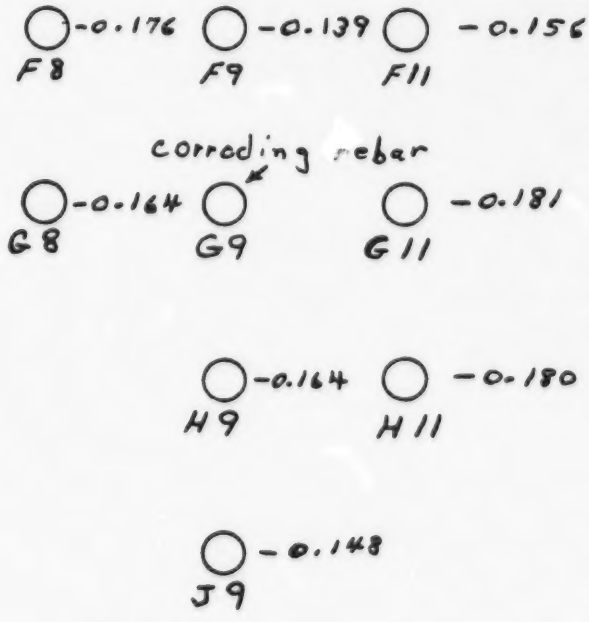


Adjacent Columns to E5-EWST

FIGURE 5



Exposed Reinforcing Rods, Column G9-EWST



Adjacent Columns to G9-EWST

FIGURE 6